3.0 IMPACTS TO WATER QUALITY

The projected impacts to water quality from the discharge associated with CBNG development in each subwatershed are described in this chapter. Three graphs are utilized to depict the projected impact for the current conditions (2003) and each of three future RFD scenarios for years 2010, 2015, and 2020. These graphs include:

- illustration of EC for mean monthly flows before and after mixing with projected CBNG discharges;
- illustration of SAR for mean monthly flows before and after mixing with projected CBNG discharges; and an
- illustration of projected water quality (for irrigation purposes) for mean monthly flows for both EC and SAR in relation to the Ayers-Westcot EC-SAR threshold.

The first two graphs include lines depicting the LRPL and MRPL to facilitate evaluation of the impacts. With respect to the third graph, water quality that meets the proposed EC and SAR limits as well as the Ayers-Westcot threshold should fall to the left of the proposed EC limit, below the proposed SAR limit and below and to the right of the diagonal line on the graphs.

As indicated in Chapter 2, the impacts to water quality on the receiving drainages assumed two hydrologic conditions; dry-year conditions and normal-year conditions. The impact analysis was conducted using monthly flows and comparatively evaluated the water quality parameters (SAR and EC) of the receiving drainage before and after mixing with discharge water generated by the CBNG wells within the watershed. In general, the water discharged from the CBNG wells reflected increased levels of SAR and reduced levels of EC compared to the water quality of the receiving drainages. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions. Detailed results of the comparative evaluation all monthly flows associated with the dry-year and normal-year hydrologic conditions are presented in Appendix C.

3.1 Antelope Creek

Results of the impacts to water quality in the Antelope Creek subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.1-1**. **Table 3.1-1**

reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year hydrologic condition and the normal-year hydrologic condition. The information in **Table 3.1-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow for each RFD scenario. As noted above, impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs.

Table 3.1-1 Surface Water Impact Analysis of the Antelope Creek Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	0.31	2.79	2372	1.21	6.38	1299
2010	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	3.61	7.20	1053
2015	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	4.41	7.28	1031
2020	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	4.21	1.26	1036
Dry Year										
2003	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	0.10	2.79	2005	1.03	7.01	1065
2010	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	3.43	7.43	970
2015	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	4.23	7.47	963
2020	10[(1)]	2000[(1)]	10[(2)]	2500[(2)]	---	---	---	4.03	7.46	964

[(1)] Wyoming DEQ

[(2)] South Dakota's Legislative Council

The peak CBNG discharge in the watershed is realized for RFD Scenario 2015 when 4.1 cfs is conveyed into Antelope Creek. The quantity of water discharged into Antelope Creek would be less in the other RFD scenarios and would consequently result in a reduction in impacts to the existing water quality. For RFD Scenario 2015, the dry-year hydrologic conditions presented in **Table 3.1-1** illustrate the impacts associated with mixing 0.13 cfs of streamflow in Antelope Creek with 4.1 cfs of CBNG well discharge water on both SAR and EC. After the flows mix, the resultant streamflow consists almost entirely of CBNG produced water. The resulting EC would decrease, whereas the SAR would increase compared to existing stream water quality conditions (see water quality input data in Appendix B). The combined streamflow of approximately 4.2

cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to be adequate to meet the MRPL and LRPL for both SAR and EC.

3.1.1 Antelope Creek: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.1-1, 3.1-2, 3.1-3, 3.1-4, 3.1-5 and 3.1-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For the current conditions (2003), the observations presented below are based on the information presented in these figures.

- Before Mixing. Mean monthly EC values in Antelope Creek currently exceed the MRPL during low-flow conditions (September through February), but are less than the LRPL for both the dry year and normal year. Mean monthly SAR values are currently less than the MRPL and LRPL for SAR under similar hydrologic conditions.
- Following Mixing . The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year. The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.
- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, primarily for the months of June and August during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation.

3.1.2 Antelope Creek: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.1-1, 3.1-2, 3.1-3, 3.1-4, 3.1-5 and 3.1-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For RFD Scenario 2010, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.1.1.

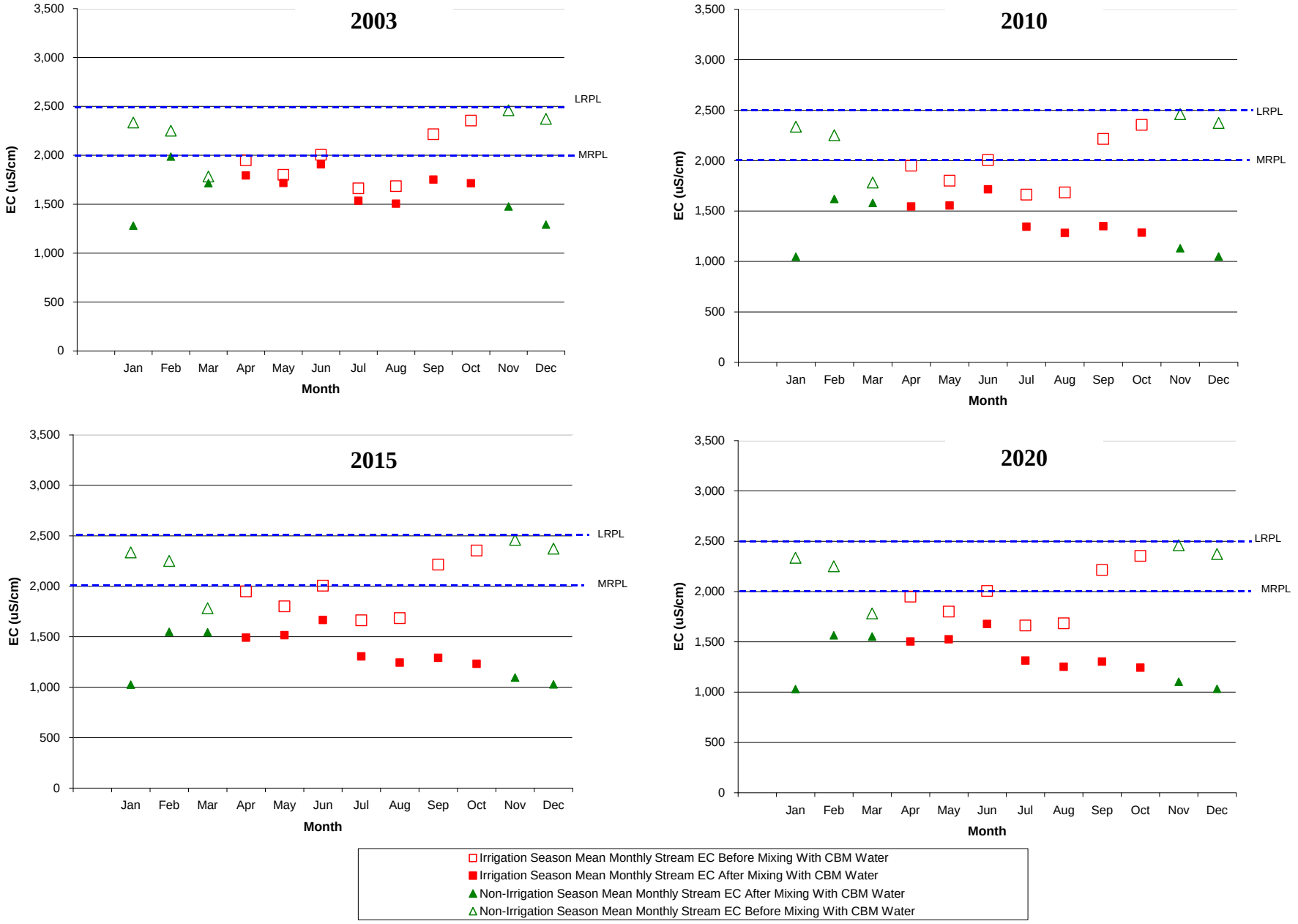

Figure 3.1-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Antelope Creek near Teckla, WY (06364700)

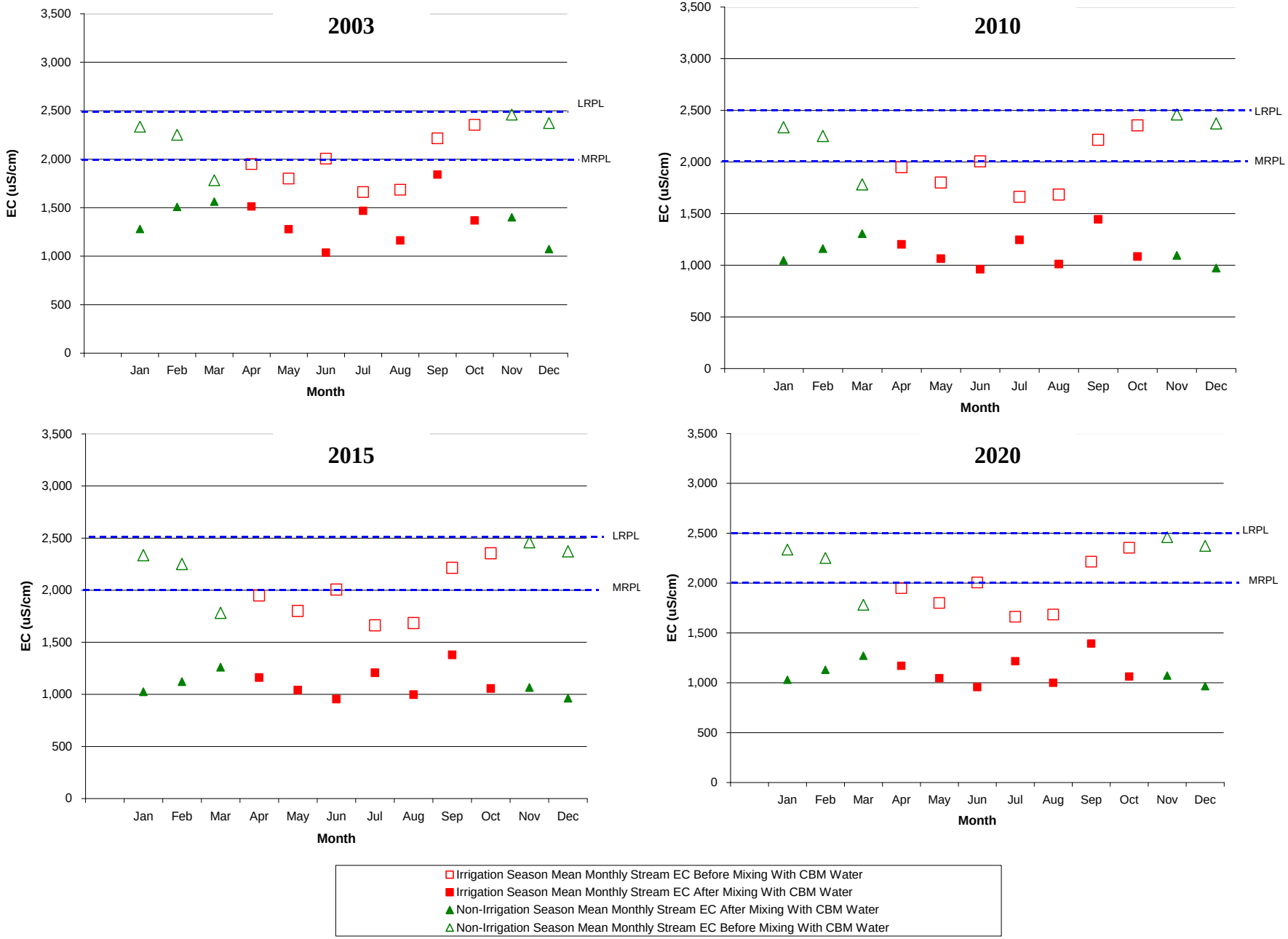

Figure 3.1-2
Stream EC Before and After Mixing with CBM Produced Water for Mean Monthly Flows- Dry Year Hydrology Antelope Creek near Teckla, WY (06364700)

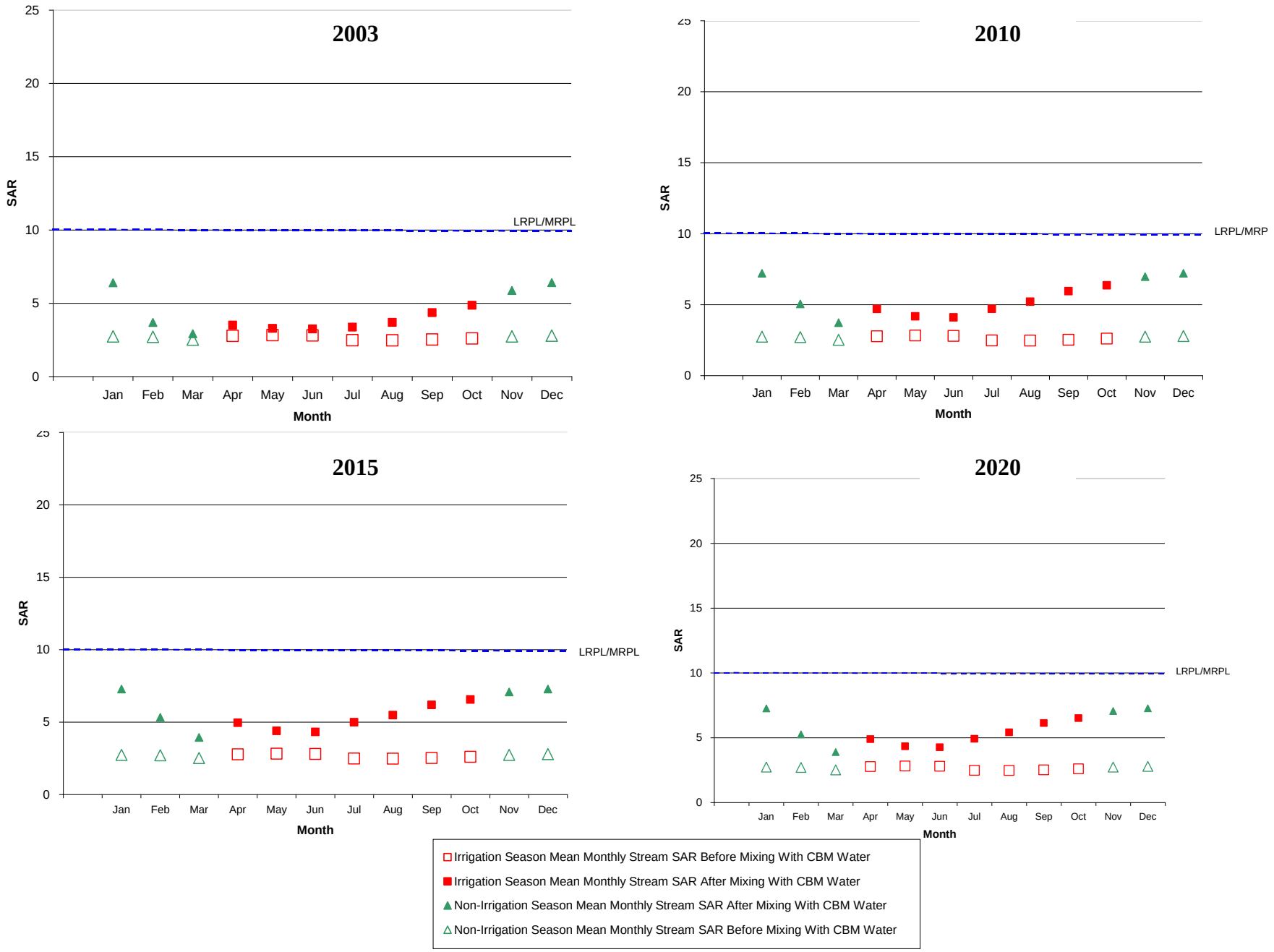

Figure 3.1-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Antelope Creek near Teckla, WY (06364700)

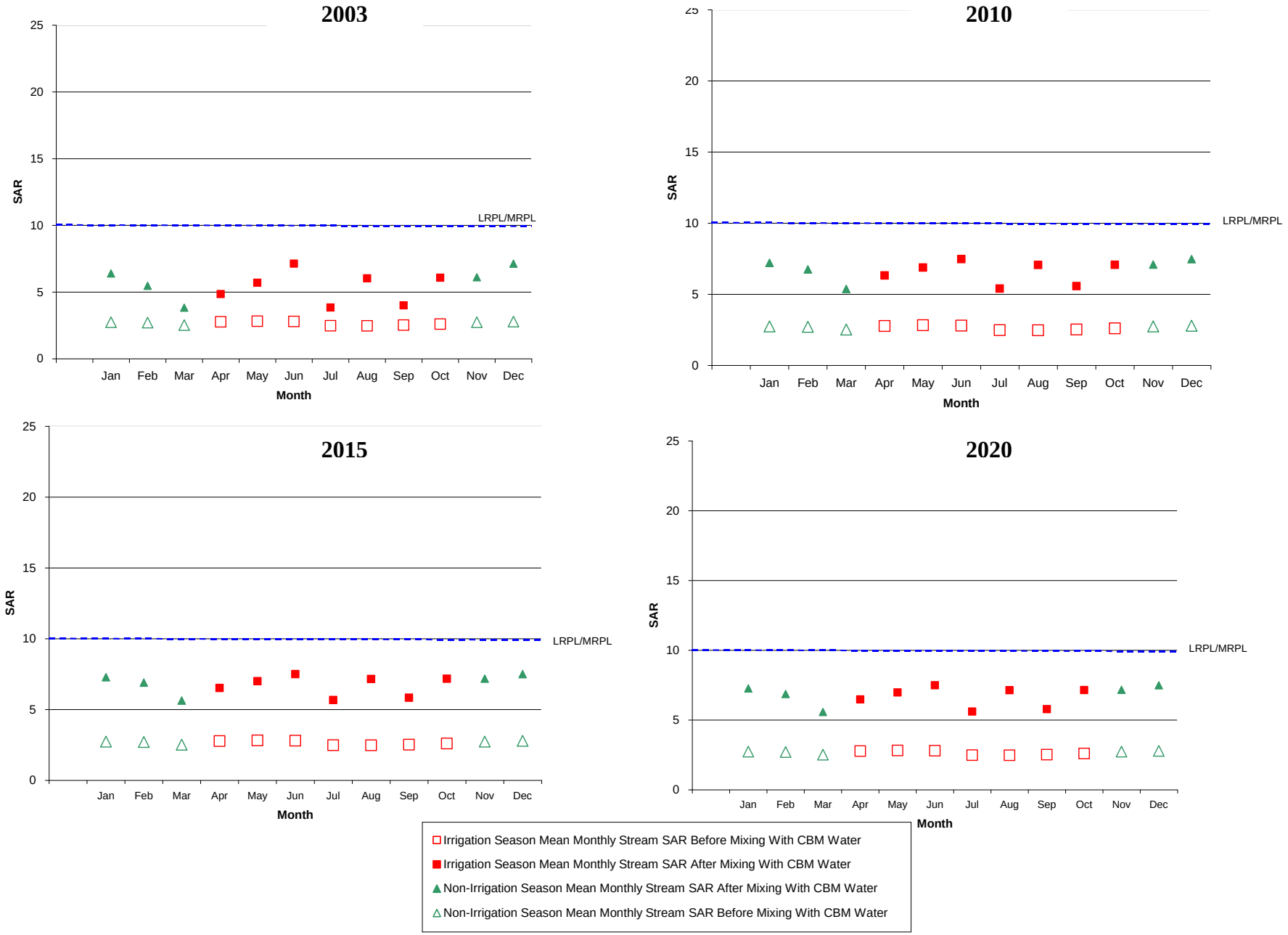

Figure 3.1-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Antelope Creek near Teckla, WY (06364700)

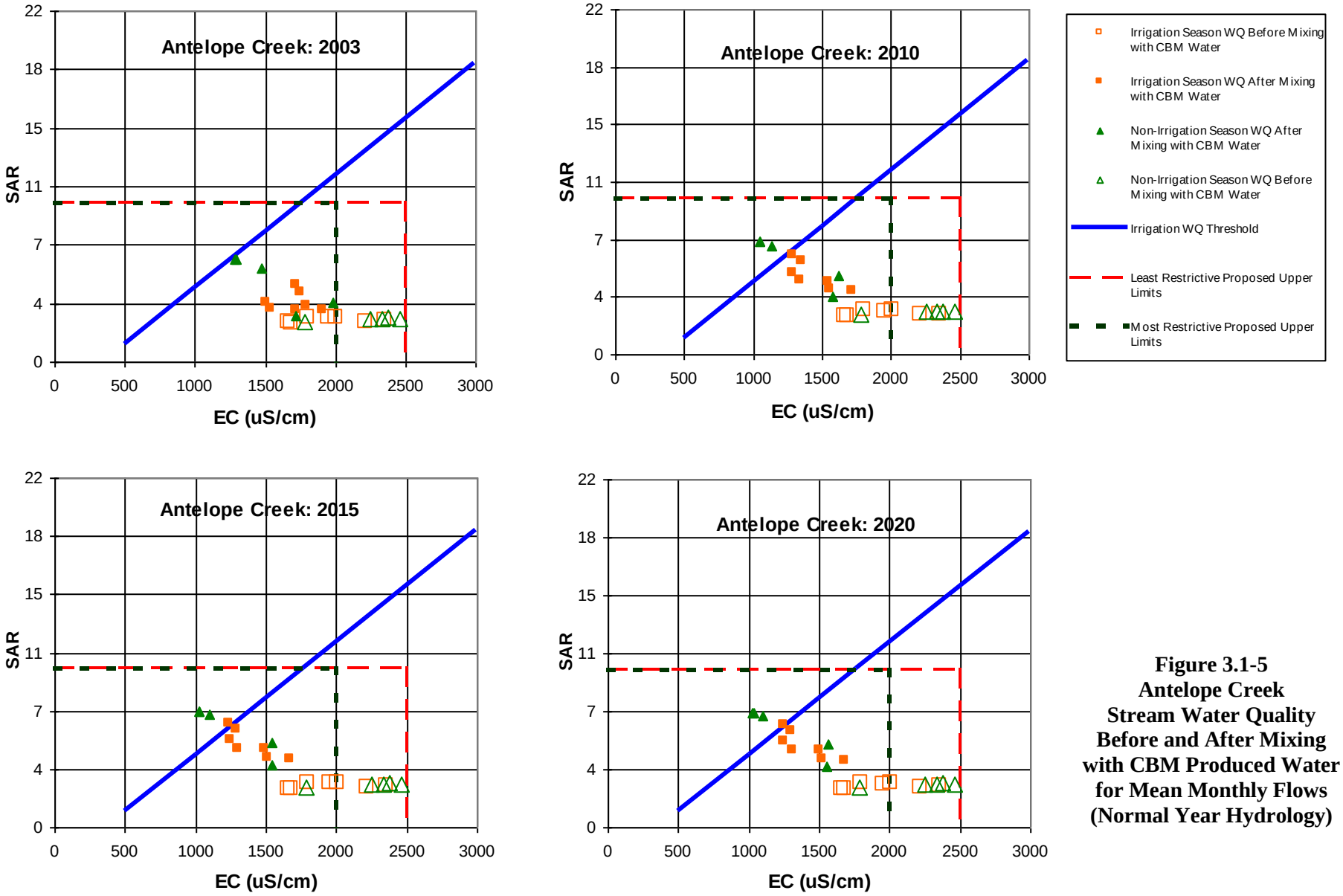

Figure 3.1-5
Antelope Creek
Stream Water Quality
Before and After Mixing
with CBM Produced Water
for Mean Monthly Flows
(Normal Year Hydrology)

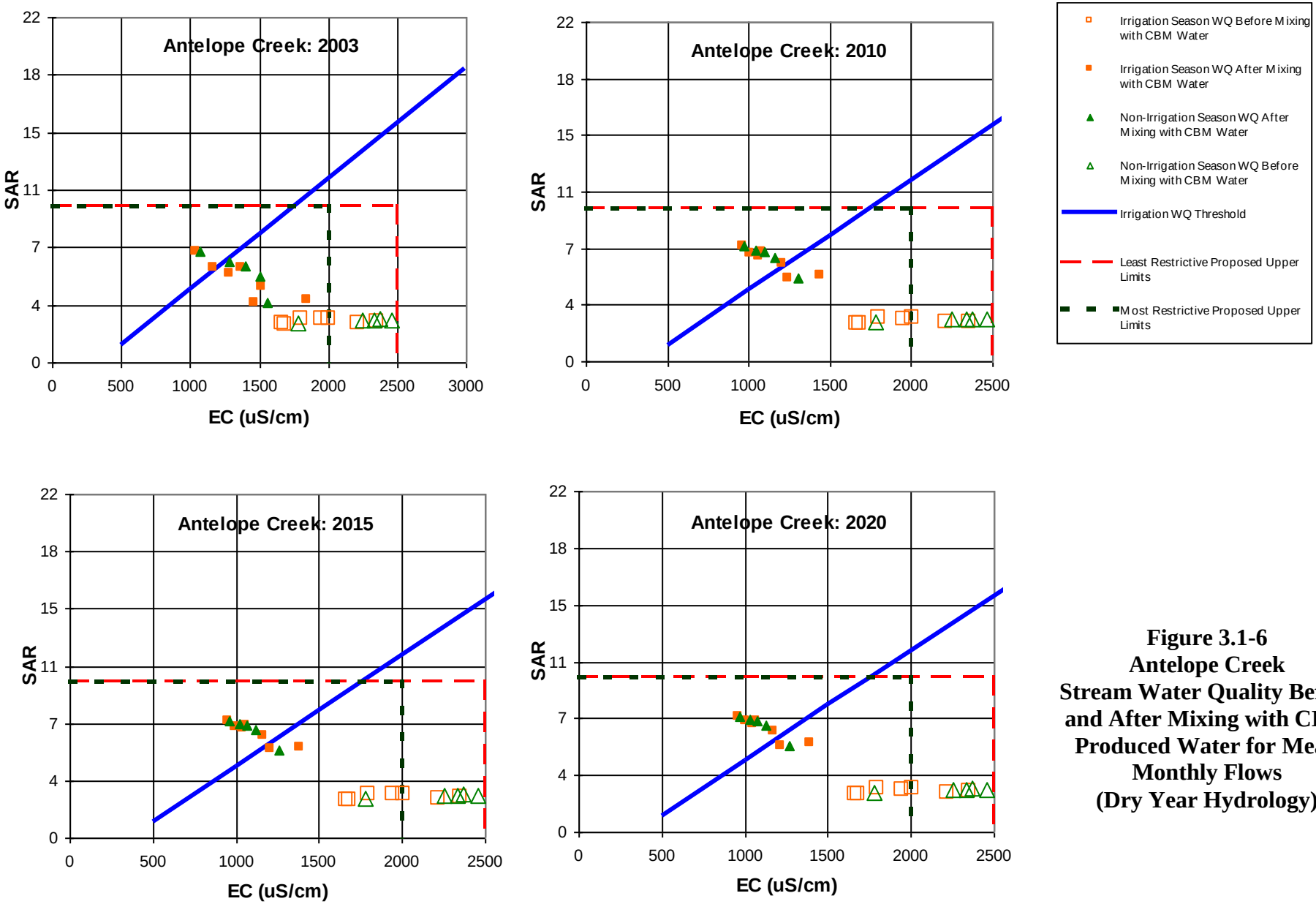

Figure 3.1-6
Antelope Creek
Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows
(Dry Year Hydrology)

- Following Mixing. The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year. The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.

- Ayers and Westcot Diagram. For dry-year conditions, the data indicated a significant reduction in infiltration throughout the irrigation season following mixing with CBNG production water and is unsuitable for irrigation except for July and September. Under normal-year conditions, a decrease in infiltration is realized following mixing with CBNG production water; overall, however, the data indicates that the mixed water is suitable for irrigation.

3.1.3 Antelope Creek: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.1-1, 3.1-2, 3.1-3, 3.1-4, 3.1-5 and 3.1-6**. For RFD Scenario 2015, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.1.1.

- Following Mixing. The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year. The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.

- Ayers and Westcot Diagram. For dry-year conditions, the data continued to indicate a significant reduction in infiltration throughout the irrigation season following mixing with CBNG production water and is unsuitable for irrigation except for July and September. Under normal-year conditions, a decrease in infiltration is realized following mixing with CBNG production water; overall, however, the data generally indicates that the mixed water is suitable for irrigation with the exception of October..

3.1.4 Antelope Creek: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are also presented in **Figures 3.1-1, 3.1-2, 3.1-3 and 3.1-4, 3.1-5 and 3.1-6**. For RFD Scenario 2020, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.1.1.

- Following Mixing. The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year. The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.

- Ayers and Westcot Diagram. For dry-year conditions, the data continued to indicate a significant reduction in infiltration throughout the irrigation season following mixing with CBNG production water and is unsuitable for irrigation except for July and September. Under normal-year conditions, a decrease in infiltration is realized following mixing with CBNG production water; overall, however, the data generally indicates that the mixed water is suitable for irrigation with the exception of October.

3.2 Dry Fork Cheyenne River

Results of the impacts to water quality in the Dry Fork Cheyenne River subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.2-1**. **Table 3.2-1** reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year and normal-year hydrologic conditions. As stated previously, the information in **Table 3.2-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow in the Dry Fork Cheyenne River for each RFD scenario. As noted above, impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions. For the Dry Fork Cheyenne River, the minimum monthly flow for both hydrologic conditions is zero (0) cfs and occurs for several months of the year during the dry-year condition.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs.

Table 3.2-1 Surface Water Impact Analysis of the Dry Fork Cheyenne River Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	0	---	---	0.00	---	---
2010	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.03	7.62	929
2015	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.04	7.62	929
2020	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.04	7.62	929
Dry Year										
2003	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	0	---	---	0.00	---	---
2010	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.03	7.62	929
2015	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.04	7.62	929
2020	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	0.04	7.62	929

[(1)] Wyoming DEQ

The peak CBNG discharge in the watershed is similar for RFD Scenarios 2015 and 2020 and reflects approximately 0.04 cfs conveyed into the Dry Fork Cheyenne River. The quantity of water discharged into the Dry Fork Cheyenne River would be less in the other RFD scenarios but results in similar impacts to the existing water quality since no flow is available under either hydrologic condition. For RFD Scenario 2120, the dry-year hydrologic conditions presented in **Table 3.2-1** illustrate the impacts associated with mixing 0 cfs of streamflow in the Dry Fork Cheyenne River with 0.04 cfs of CBNG well discharge water on both SAR and EC. Consequently, the resultant streamflow consists entirely of CBNG produced water. Compared to typical values when streamflow is available in the river (see water quality input data in Appendix B), the resulting EC would decrease, whereas the SAR would increase. The combined streamflow of approximately 0.04 cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to be adequate to meet the MRPL and LRPL for both SAR and EC.

3.2.1 Dry Fork Cheyenne River: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.2-1, 3.2-2, 3.2-3, 3.2-4, 3.2-5 and 3.2-6**. No CBNG production water is included in the evaluation of current conditions (2003) since no wells have been identified that discharge to the Dry Fork Cheyenne River. Given the information in the referenced figures, the observations presented below represent the existing water quality in the river for both hydrologic conditions.

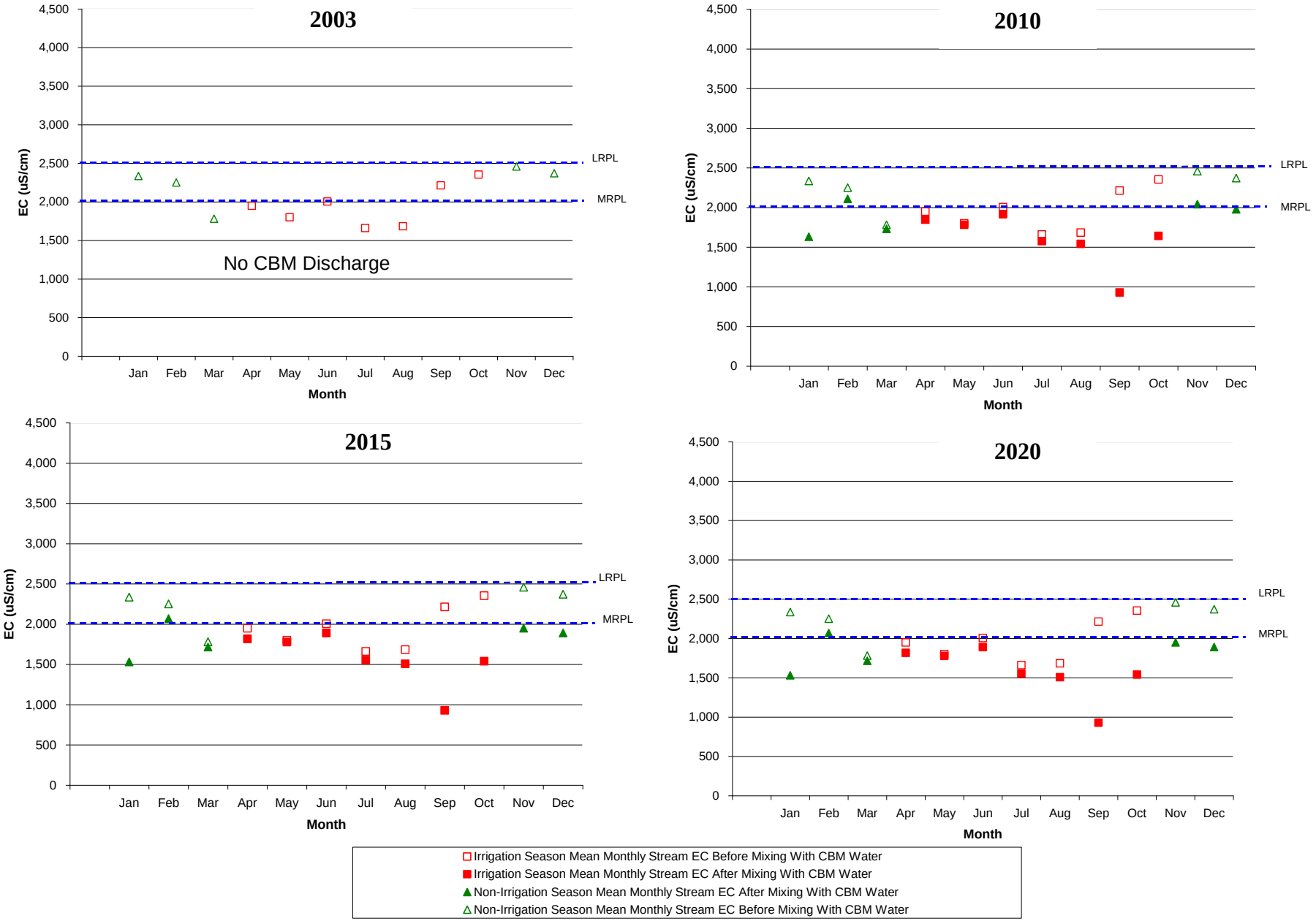

Figure 3.2-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Dry Fork Cheyenne River Near Bill, Wyoming (0634700)

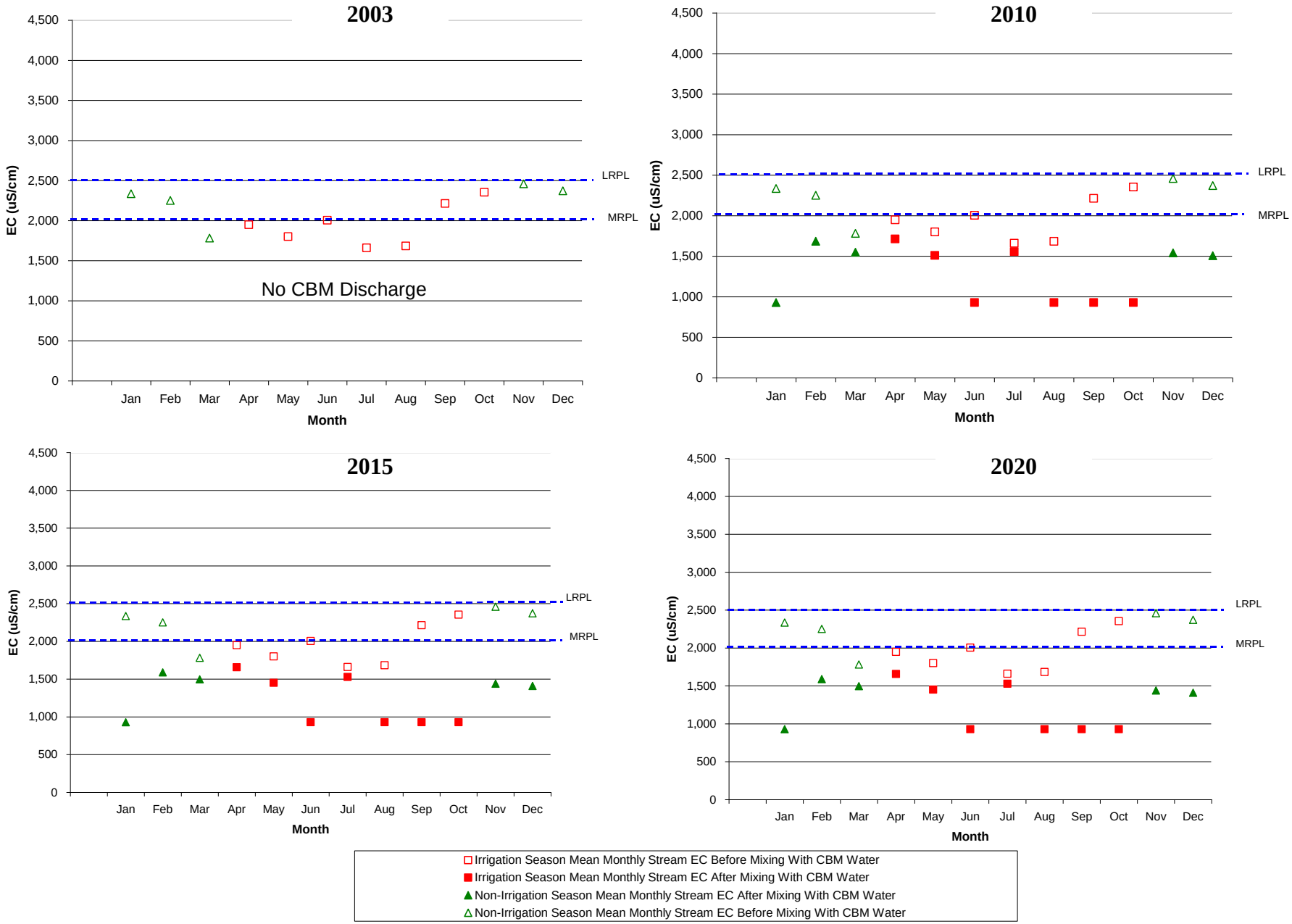

Figure 3.2-2
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Dry Fork Cheyenne River Near Bill, Wyoming (0634700)

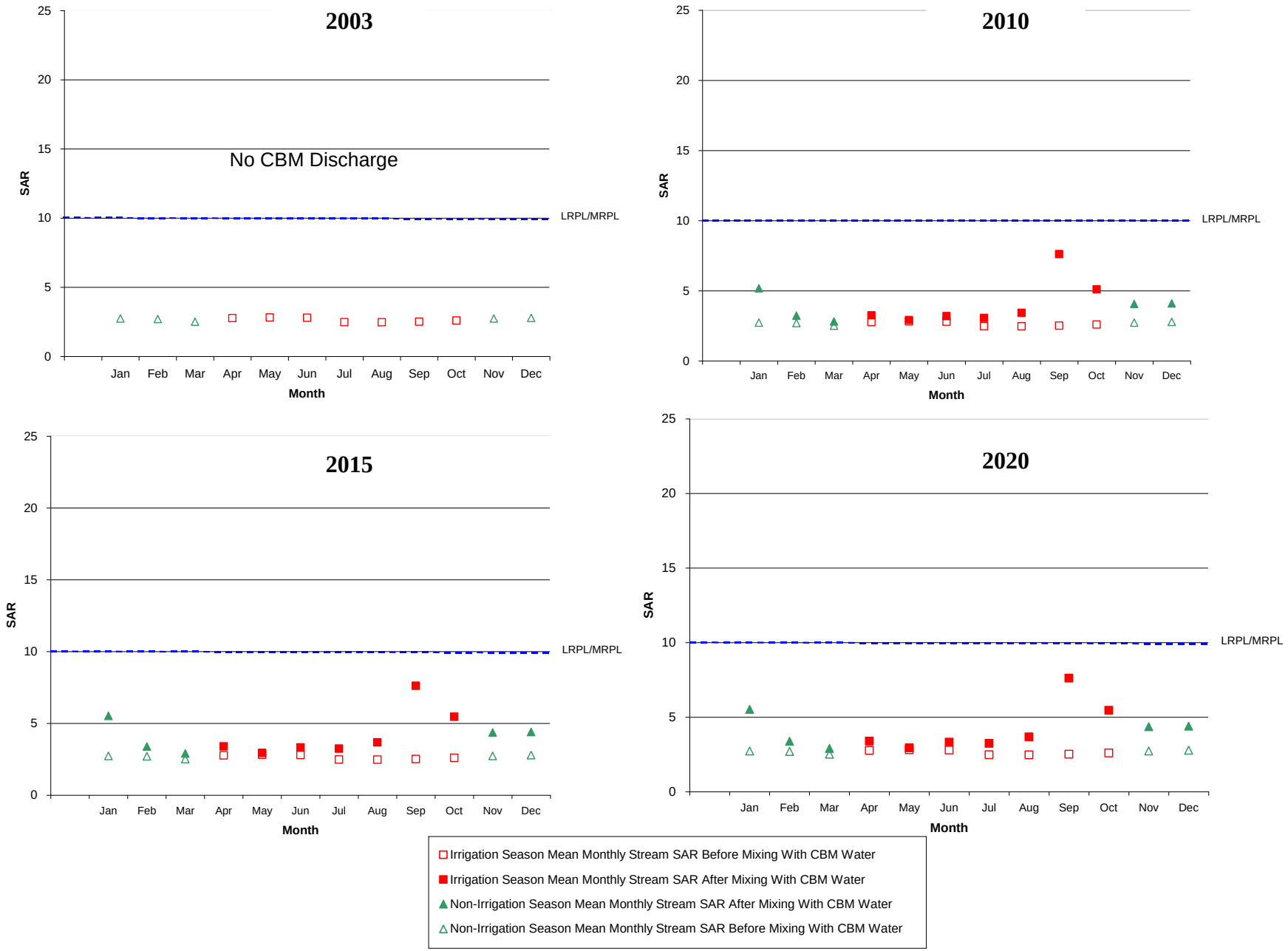

Figure 3.2-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Dry Fork Cheyenne River Near Bill, Wyoming (0634700)

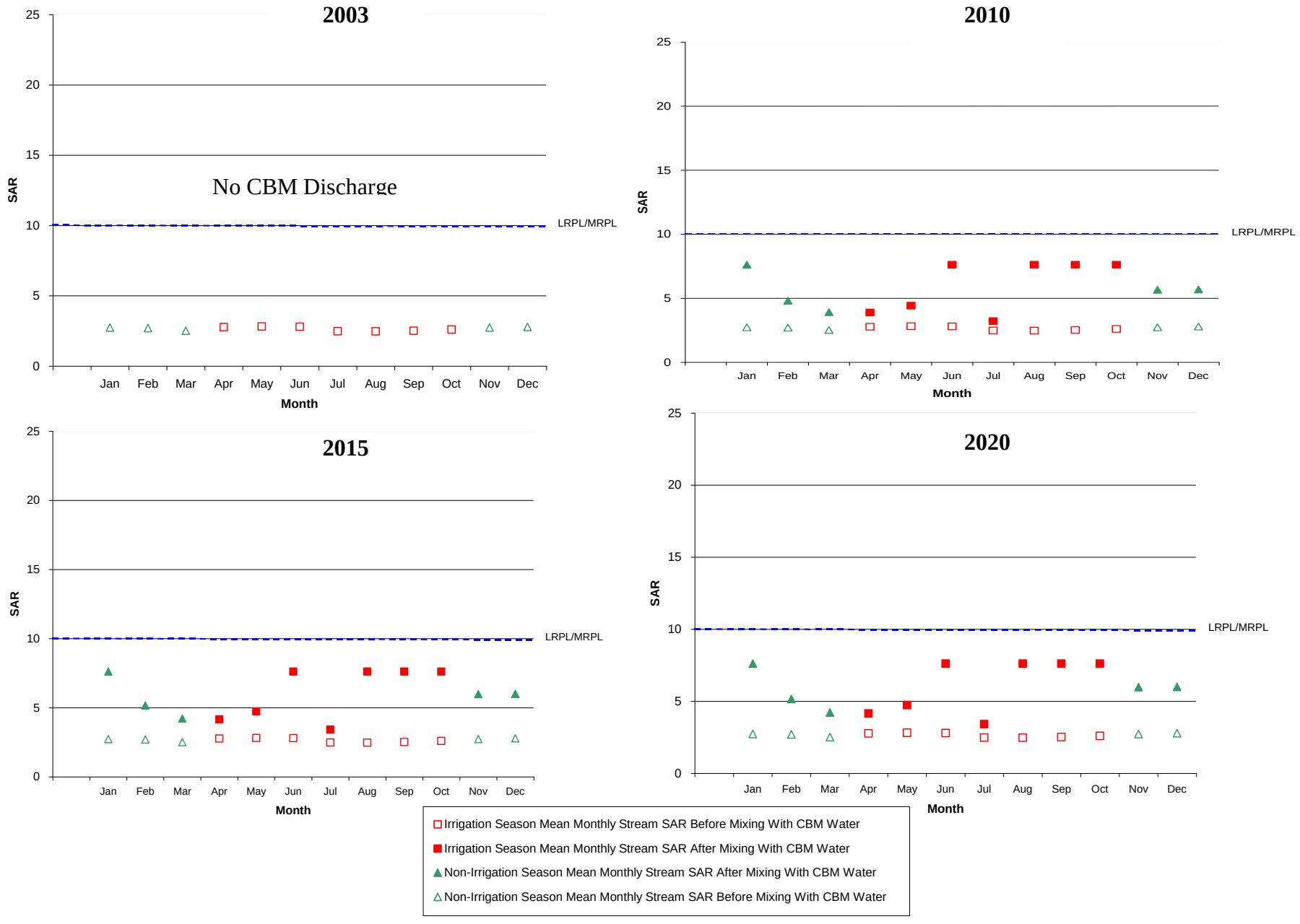

Figure 3.2-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Dry Fork Cheyenne River Near Bill, Wyoming (0634700)

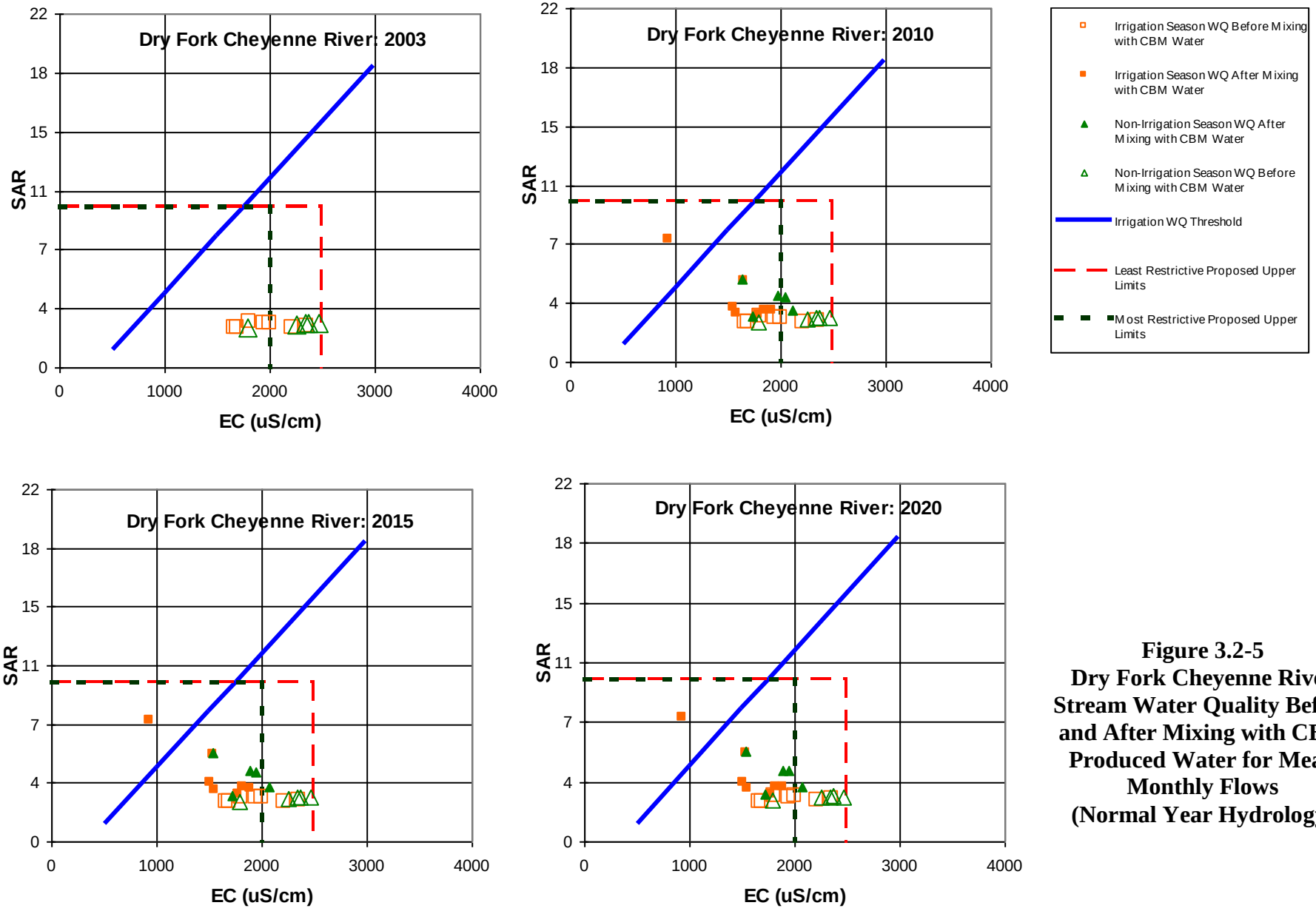

Figure 3.2-5
Dry Fork Cheyenne River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Normal Year Hydrology)

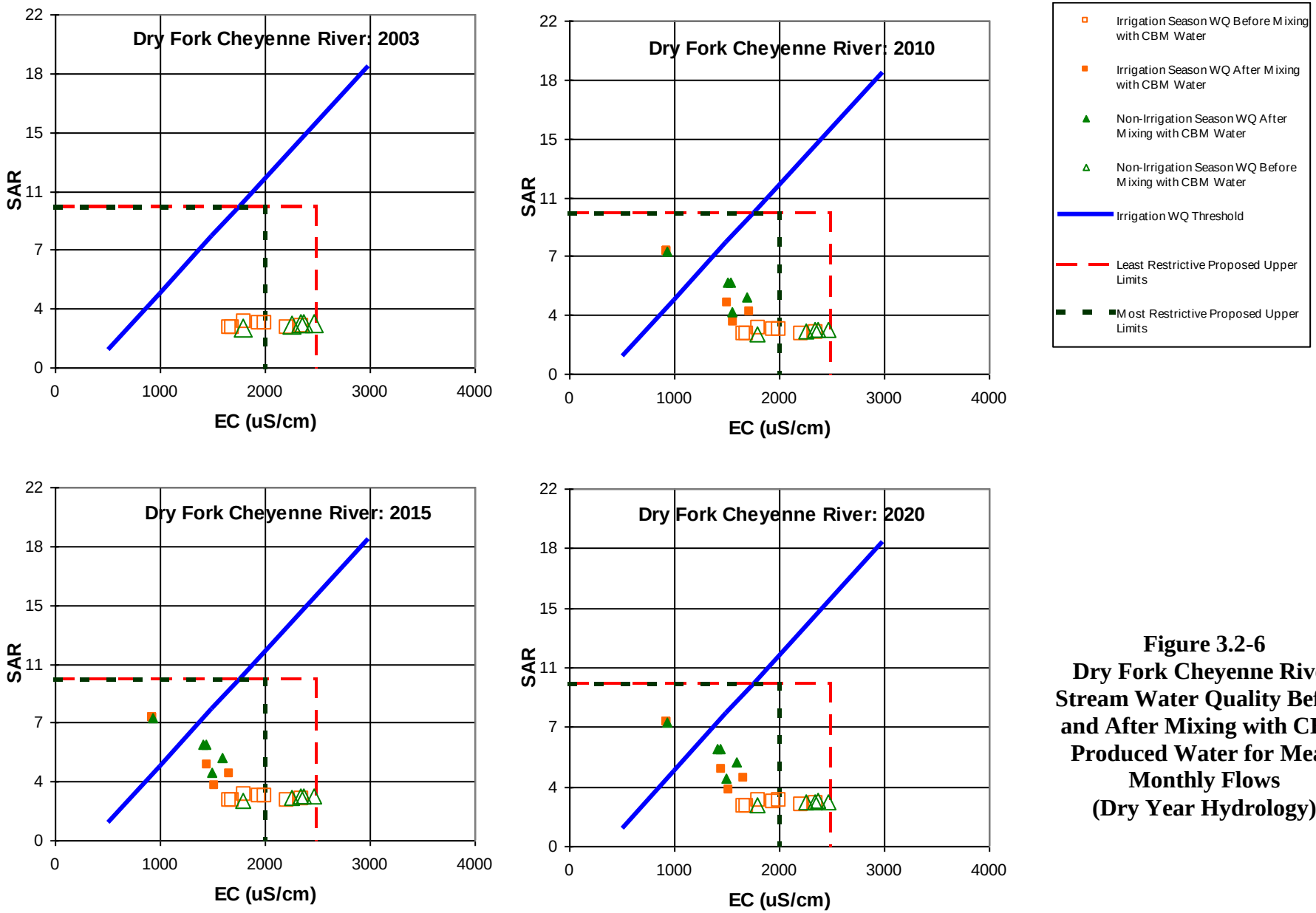

Figure 3.2-6
Dry Fork Cheyenne River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Dry Year Hydrology)

- Mean monthly EC values in the Dry Fork Cheyenne River currently exceed the MRPL, during the low flow months from September through February. All mean monthly values meet the LRPL criteria for EC.
- Mean monthly SAR values are currently less than the MRPL and LRPL under similar flow conditions.
- The data obtained from the Ayers and Westcot Diagram for the current conditions indicates that the existing water in the Dry Fork Cheyenne River is suitable for irrigation.

3.2.2 Dry Fork Cheyenne River: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.2-1, 3.2-2, 3.2-3, 3.2-4, 3.2-5 and 3.2-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For RFD Scenario 2010, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.2.1.
- Following Mixing. The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year (with the exception of February and November). The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.
- Ayers and Westcot Diagram. For dry-year conditions, the flow in the river is entirely or largely composed of CBNG production water. Given the water quality of the CBNG production water, a significant reduction in infiltration is noted throughout the irrigation season and the mixed water is considered unsuitable for irrigation (June, August through September); the unsuitable nature of the water is largely attributed to the elevated levels of SAR. Under normal-year conditions, a minor decrease in infiltration is realized following mixing with CBNG production water; overall, however, the data indicates that the mixed water is suitable for irrigation with the exception of the month of September.

3.2.3 Dry Fork Cheyenne River: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.2-1, 3.2-2, 3.2-3, 3.2-4, 3.2-5 and 3.2-6**. For RFD Scenario 2015, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.2.1.
- Following Mixing. The resultant EC values decrease sufficiently to meet the LRPL and MRPL for EC for both the dry year and normal year (with the exception of February). The resultant SAR values increase but continue to meet the LRPL and MRPL for SAR for both hydrologic conditions.
- Ayers and Westcot Diagram. For dry-year conditions, the flow in the river is entirely or largely composed of CBNG production water. Given the water quality of the CBNG production water, a significant reduction in infiltration is noted throughout the irrigation season and the mixed water is considered unsuitable for irrigation (June, August through September); the unsuitable nature of the water is largely attributed to the elevated levels of SAR. Under normal-year conditions, a minor decrease in infiltration is realized following mixing with CBNG production water; overall, however, the data indicates that the mixed water is suitable for irrigation with the exception of the month of September.

3.2.4 Dry Fork Cheyenne River: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are also presented in Figures **3.2-1, 3.2-2, 3.2-3, 3.2-4, 3.2-5 and 3.2-6**. The observations presented for RFD Scenario 2015 are identical for RFD Scenario 2020 given the CBNG production water remains constant for both scenarios.

3.3 Little Powder River

Results of the impacts to water quality in the Little Powder River subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.3-1**. **Table 3.3-1** reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year and normal-year hydrologic conditions. As stated previously, the information in **Table 3.3-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow in the Little Powder River for

each RFD scenario. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs.

Table 3.3-1 Surface Water Impact Analysis of the Little Powder River Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	1.05	6.94	3300	2.7	9.08	2219
2010	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	3.3	9.34	2088
2015	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	2.2	9.31	2106
2020	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	2.9	9.18	2169
Dry Year										
2003	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	0.22	6.44	2810	1.8	10	1666
2010	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	2.4	10.12	1627
2015	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	2.3	10.11	1632
2020	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	2.0	10.05	1651

[(1)] Montana DEQ

The peak CBNG discharge in the watershed is realized for RFD Scenario 2010 when 2.2 cfs is conveyed into the Little Powder River. The quantity of water discharged into the Little Powder River would be less in the other RFD scenarios and would consequently result in a reduction in impacts to the existing water quality. For RFD Scenario 2010, the dry-year hydrologic conditions presented in **Table 3.3-1** illustrate the impacts associated with mixing 0.22 cfs (occurring in the month of September) of streamflow in the Little Powder River with 2.2 cfs of CBNG well discharge water on both SAR and EC. After the flows mix, the resultant streamflow consists almost entirely of CBNG produced water. The resulting EC would decrease, whereas the SAR would increase compared to existing stream water quality conditions (see water quality input data in Appendix B). The combined streamflow of approximately 2.4 cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to meet the LRPL and MRPL for EC and exceeds the LRPL and MRPL for SAR.

3.3.1 Little Powder River: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.3-1, 3.3-2, 3.3-3, 3.3-4, 3.3-5 and 3.3-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For the current conditions (2003), the observations presented below are based on the information presented in these figures.

- Before Mixing. Mean monthly EC values in the Little Powder River currently exceed the MRPL for all months of the year except March, and exceed the LRPL during low-flow conditions in August, September and November through January for both the dry year and normal year. Mean monthly values currently exceed the MRPL for SAR with the exception of March and May and are less than the LRPL for both hydrologic conditions.
- Following Mixing . For the normal year, the resultant EC values decrease but continue to exceed the MRPL for EC for all months except March and May and exceed the LRPL during the low flow months of January and August. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the month of March and are less than the LRPL for the normal year. For the dry year, the EC values continue to decrease but exceed the MRPL during the months of February, April, June and August, and are less than the LRPL for all months. The resultant SAR values exceed the MRPL for all months and exceed the LRPL during the low flow conditions during the month of September.
- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the months of September through October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.3.2 Little Powder River: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.3-1, 3.3-2, 3.3-3, 3.3-4, 3.3-5 and 3.3-6**. For RFD Scenario 2010, the observations presented below are based on the information presented in these figures.

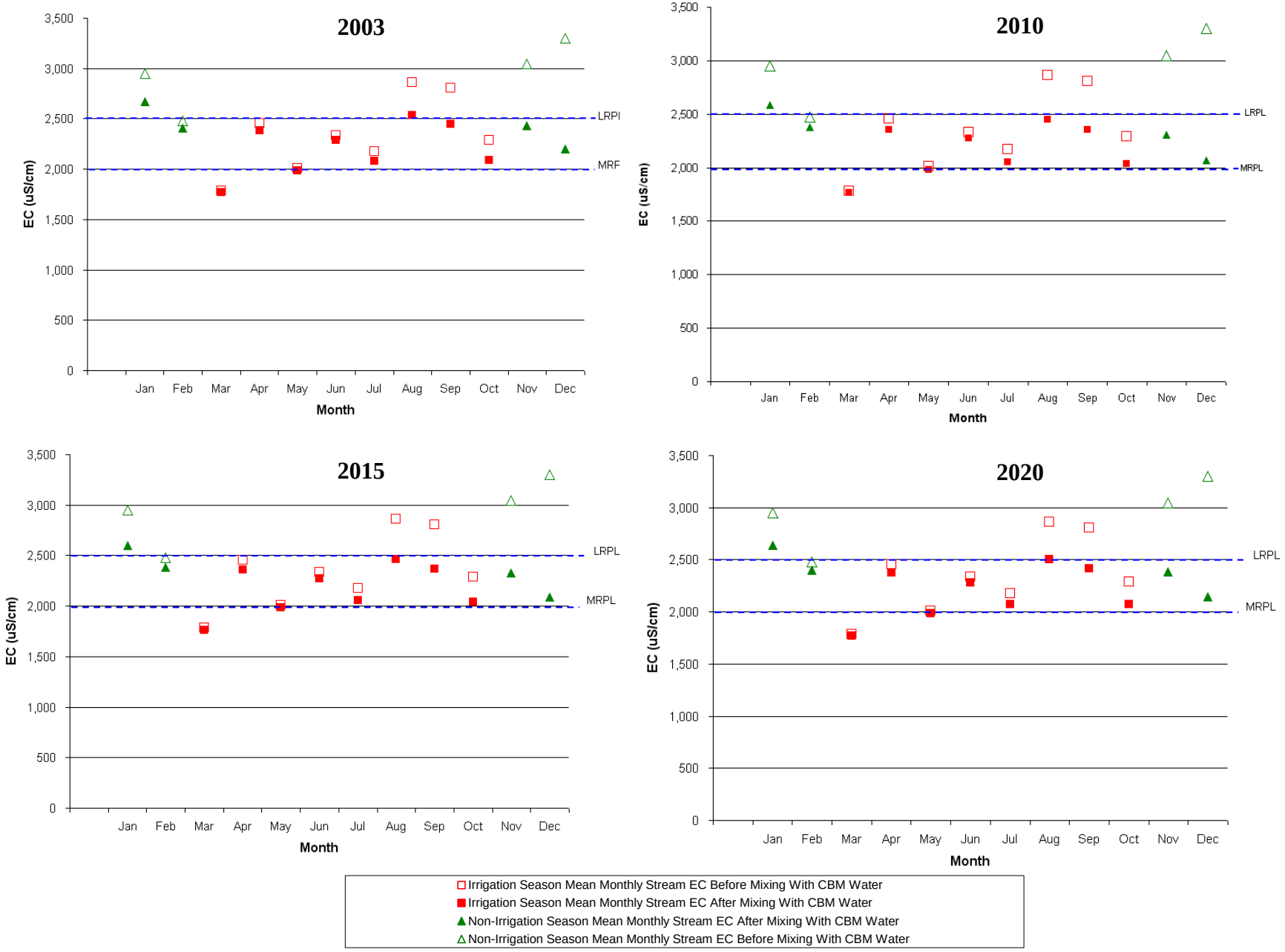

Figure 3.3-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Little Powder River near Weston, WY (06324970)

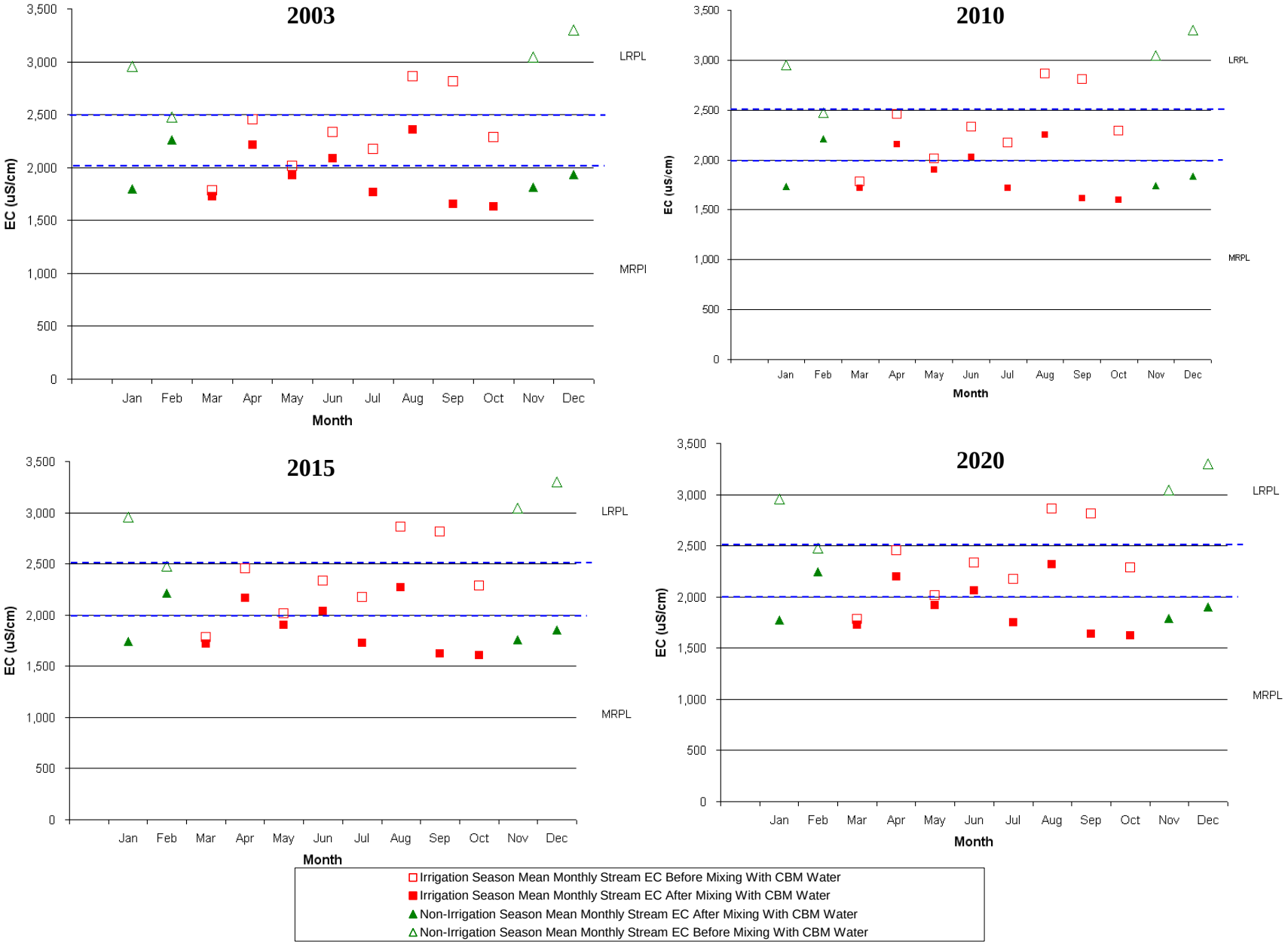

Figure 3.3-2
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Little Powder River near Weston, WY (06324970)

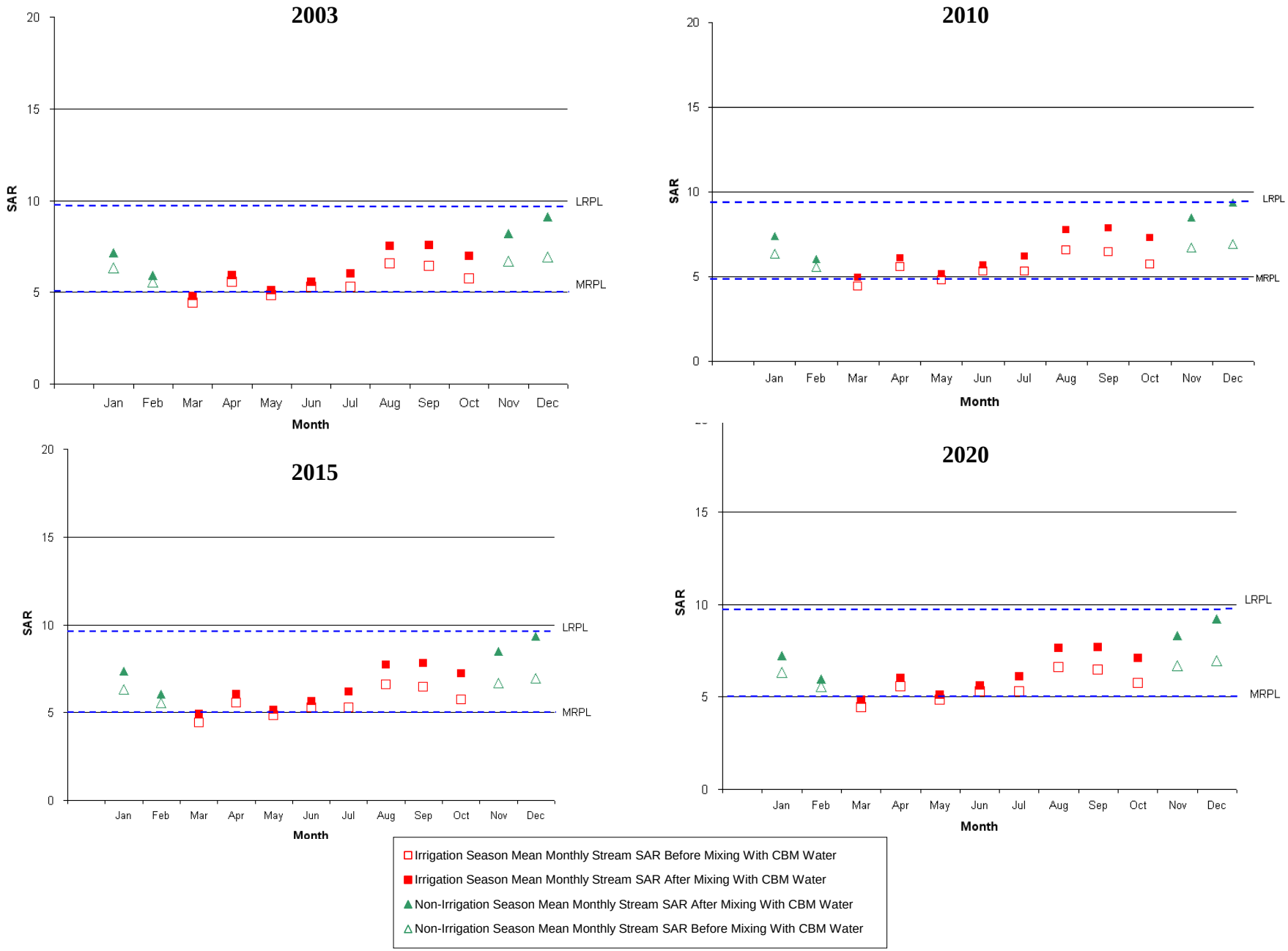

Figure 3.3-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Little Powder River near Weston, WY (06324970)

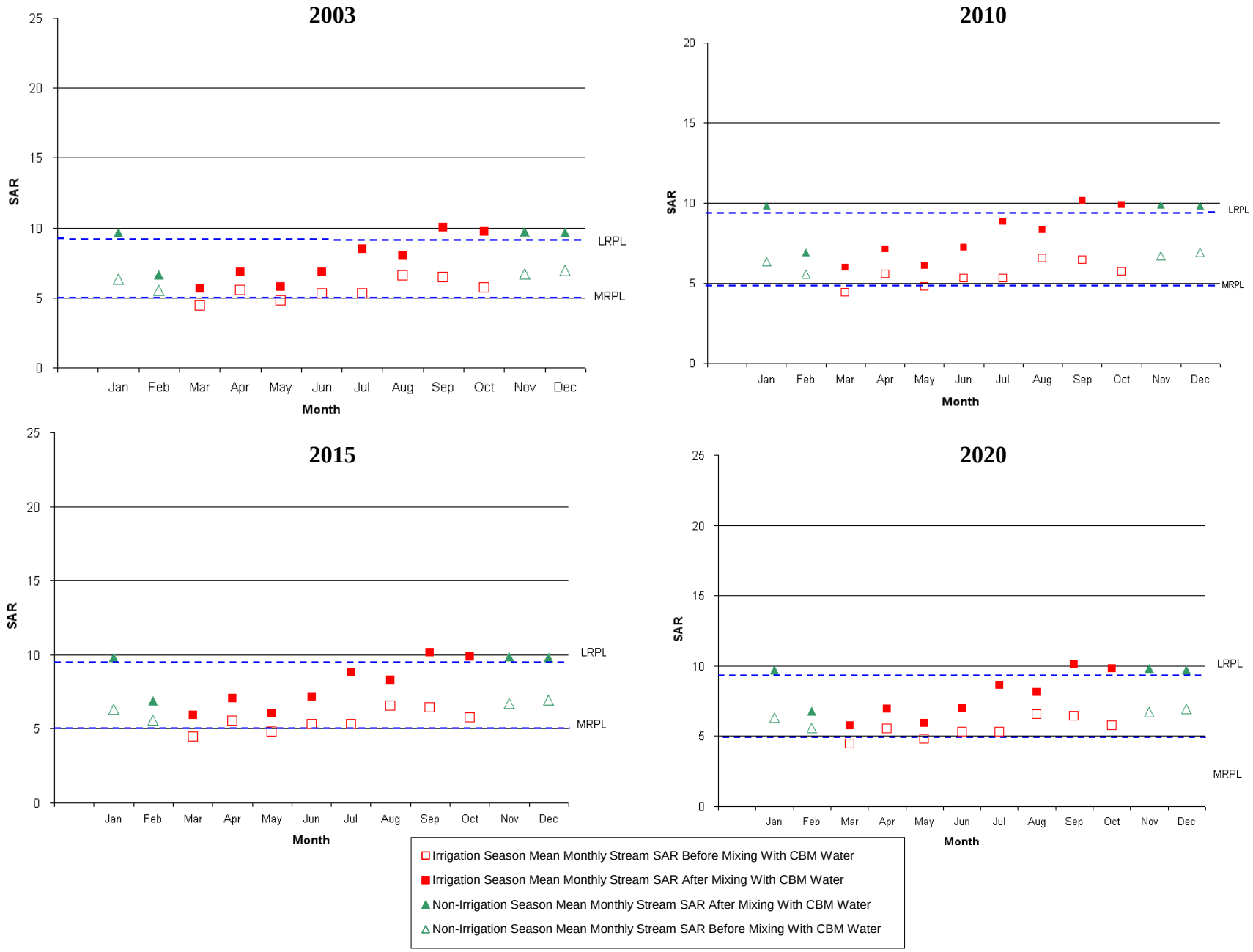

Figure 3.3-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Little Powder River near Weston, WY (06324970)

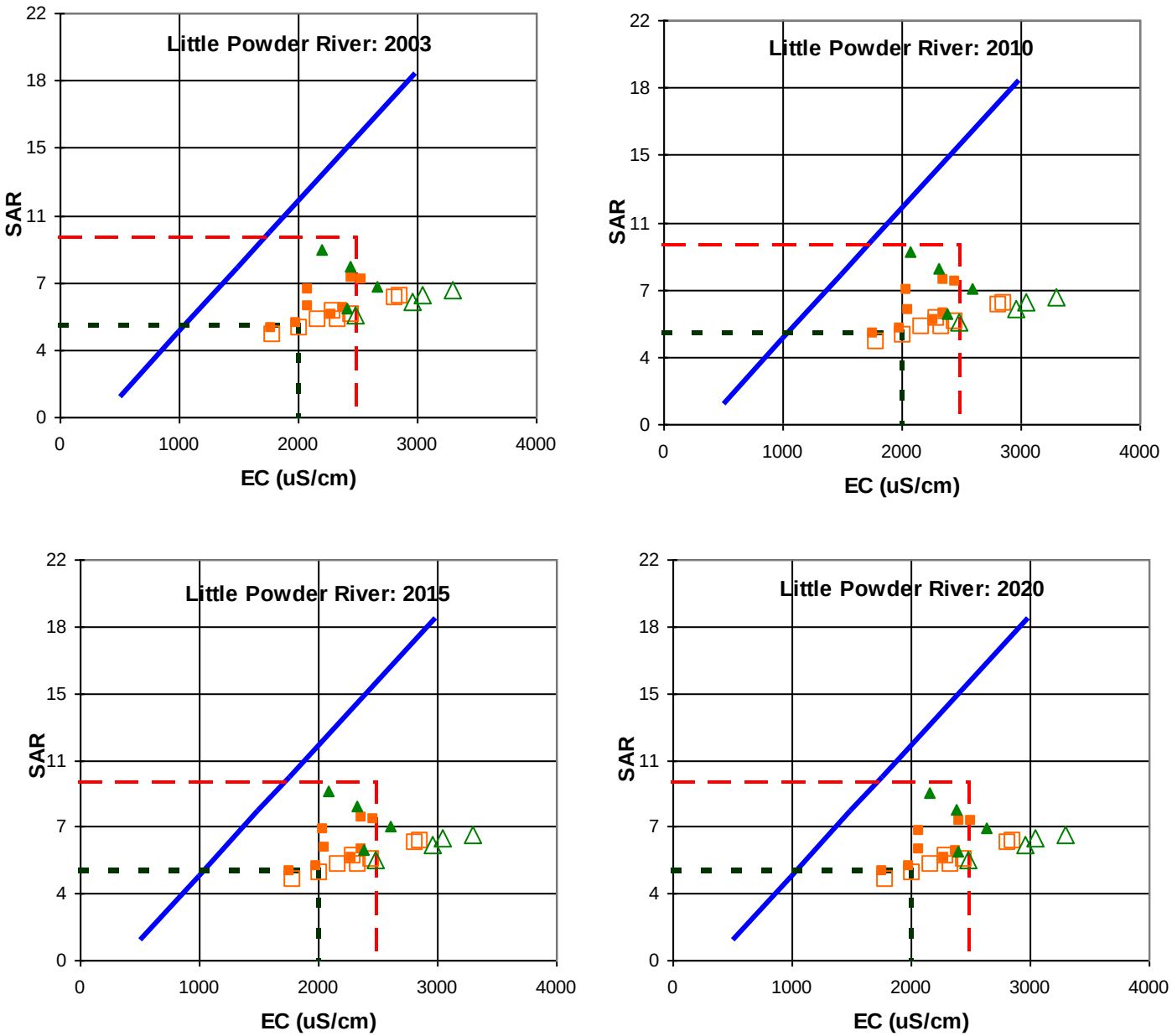

Figure 3.3-5
Little Powder River
Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows
(Normal Year Hydrology)

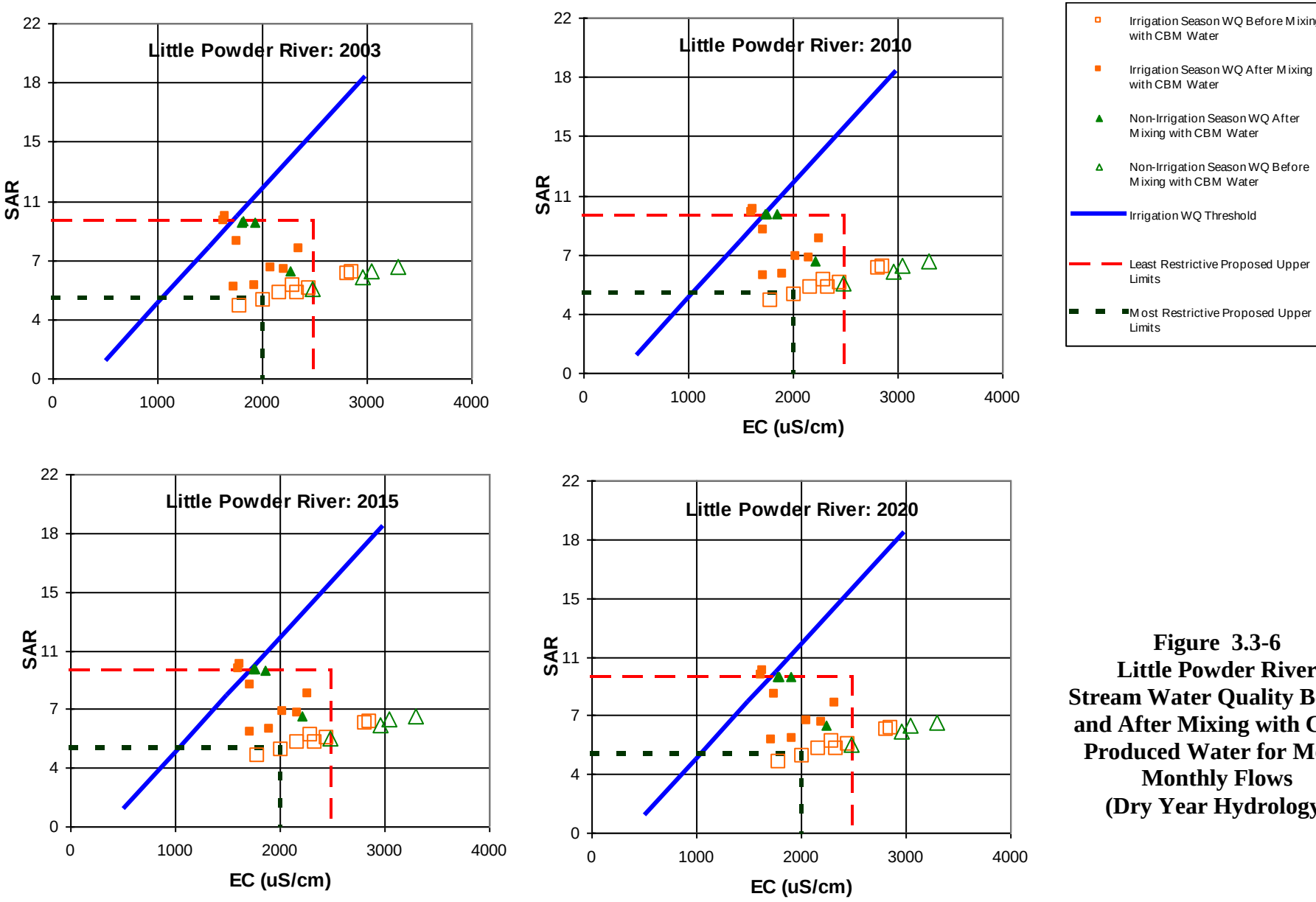

Figure 3.3-6
Little Powder River
Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows
(Dry Year Hydrology)

- Before Mixing. Same as the current conditions (2003) presented in Section 3.3.1.

- Following Mixing . For the normal year, the resultant EC values decrease but continue to exceed the MRPL for EC for all months except March and May and exceed the LRPL during the low flow month of January. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the month of March and are less than the LRPL for the normal year. For the dry year, the EC values continue to decrease but exceed the MRPL during the months of February, April, June and August, and are less than the LRPL for all months. The resultant SAR values exceed the MRPL for all months and exceed the LRPL during the low flow conditions during the months of September through January.

- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the months of September through October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.3.3 Little Powder River: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.3-1, 3.3-2, 3.3-3, 3.3-4, 3.3-5 and 3.3-6**. For RFD Scenario 2015, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.3.1.

- Following Mixing . For the normal year, the resultant EC values decrease but continue to exceed the MRPL for EC for all months except March and May and exceed the LRPL during the low flow month of January. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the month of March and are less than the LRPL for the normal year. For the dry year, the EC values continue to decrease but exceed the MRPL during the months of February, April, June and August, and are less than the LRPL for all months. The resultant SAR values exceed the MRPL for all months and exceed the LRPL during the low flow conditions during the months of September through January.

- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the months of September through October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.3.4 Little Powder River: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are also presented in Figures **3.3-1, 3.3-2, 3.3-3, 3.3-4, 3.3-5 and 3.3-6**. For RFD Scenario 2020, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.3.1.
- Following Mixing . For the normal year, the resultant EC values decrease but continue to exceed the MRPL for EC for all months except March and May and exceed the LRPL during the low flow months of January and August. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the month of March and are less than the LRPL for the normal year. For the dry year, the EC values continue to decrease but exceed the MRPL during the months of February, April, June and August, and are less than the LRPL for all months. The resultant SAR values exceed the MRPL for all months and exceed the LRPL during the low flow conditions during the months of September through November.
- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the months of September through October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.4 Upper Belle Fourche River

Results of the impacts to water quality in the Upper Belle Fourche River subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.4-1**.

Table 3.4-1 reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year and normal-year hydrologic conditions. As stated previously, the information in **Table 3.4-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow in the Upper Belle Fourche River for each RFD scenario. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs.

Table 3.4-1 Surface Water Impact Analysis of the Upper Belle Fourche River Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	3.31	6.77	2755	7.61	7.94	1825
2010	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	7.21	7.89	1865
2015	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	6.31	7.75	1973
2020	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	5.51	7.59	2098
Dry Year										
2003	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	0.42	5.75	2346	4.72	8.56	1220
2010	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	1.32	8.53	1230
2015	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	3.42	8.46	1262
2020	6[(1)]	2000[(2)]	10[(2)]	2500[(2)]	---	---	---	2.62	8.34	1308

[(1)] South Dakota's Legislative Council

[(2)] Wyoming DEQ

The peak CBNG discharge in the watershed is realized for the current conditions (i.e., 2003) when 4.3 cfs is conveyed into the Upper Belle Fourche River. The quantity of water discharged into the Upper Belle Fourche River would be less in the RFD scenarios and would consequently result in a reduction in impacts to the existing water quality. For the current conditions, the dry-year hydrologic conditions presented in **Table 3.4-1** illustrate the impacts associated with mixing 0.42 cfs (occurring in the month of October) of streamflow in the Upper Belle Fourche River with 4.3 cfs of CBNG well discharge water on both SAR and EC. After the flows mix, the resultant streamflow consists almost entirely of CBNG produced water. The resulting EC would decrease, whereas the SAR would increase compared to existing stream water quality conditions

(see water quality input data in Appendix B). The combined streamflow of approximately 4.7 cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to meet the LRPL and the MRPL for EC while the SAR value exceeds the MRPL and meets the LRPL.

3.4.1 Upper Belle Fourche River: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.4-1, 3.4-2 3.4-3, 3.4-4, 3.4-5 and 3.4-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For the current conditions (2003), the observations presented below are based on the information presented in these figures.

- Before Mixing. Mean monthly EC values in the Upper Belle Fourche River currently exceed the MRPL from September through January, and exceed the LRPL during low-flow conditions during the months from November through January for both the dry year and normal year. Mean monthly values currently exceed the MRPL for SAR from November through January and are less than the LRPL for both hydrologic conditions.
- Following Mixing . The resultant EC values decrease sufficiently to meet both the LRPL and MRPL for dry-year conditions and exceed the MRPL during October, November and January for the normal year. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the months of February, March, May and July and are less than the LRPL for the dry year. For the normal year, the resultant SAR values exceed the MRPL from August through January and are less than the LRPL for all months.
- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and is considered unsuitable for the months of August, September and October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.4.2 Upper Belle Fourche River: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.4-1, 3.4-2, 3.4-3, 3.4-4, 3.4-5 and 3.4-6**. For RFD Scenario 2010, the observations presented below are based on the information presented in these figures.

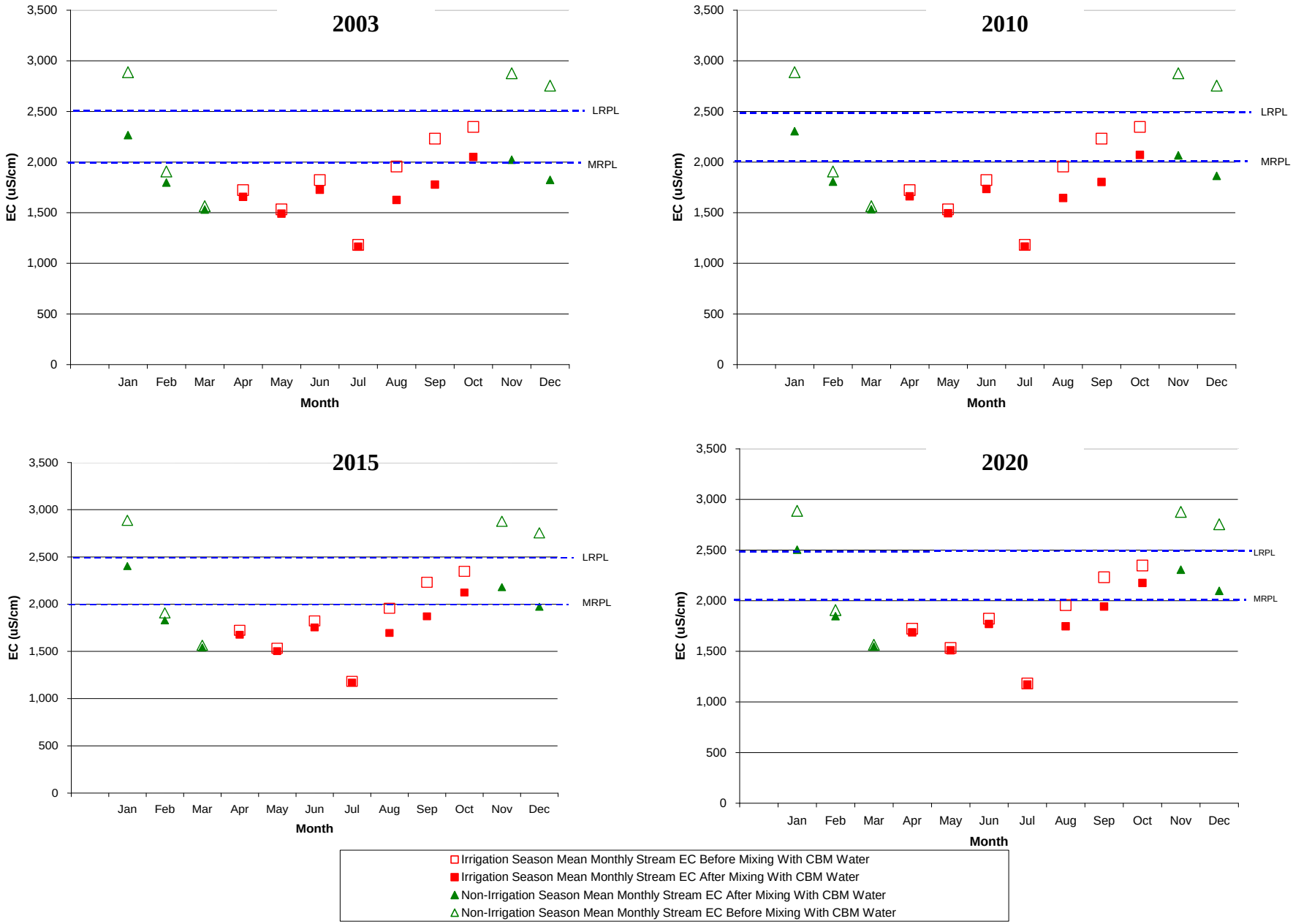

Figure 3.4-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Belle Fourche River below Moorcroft, WY (06426500)

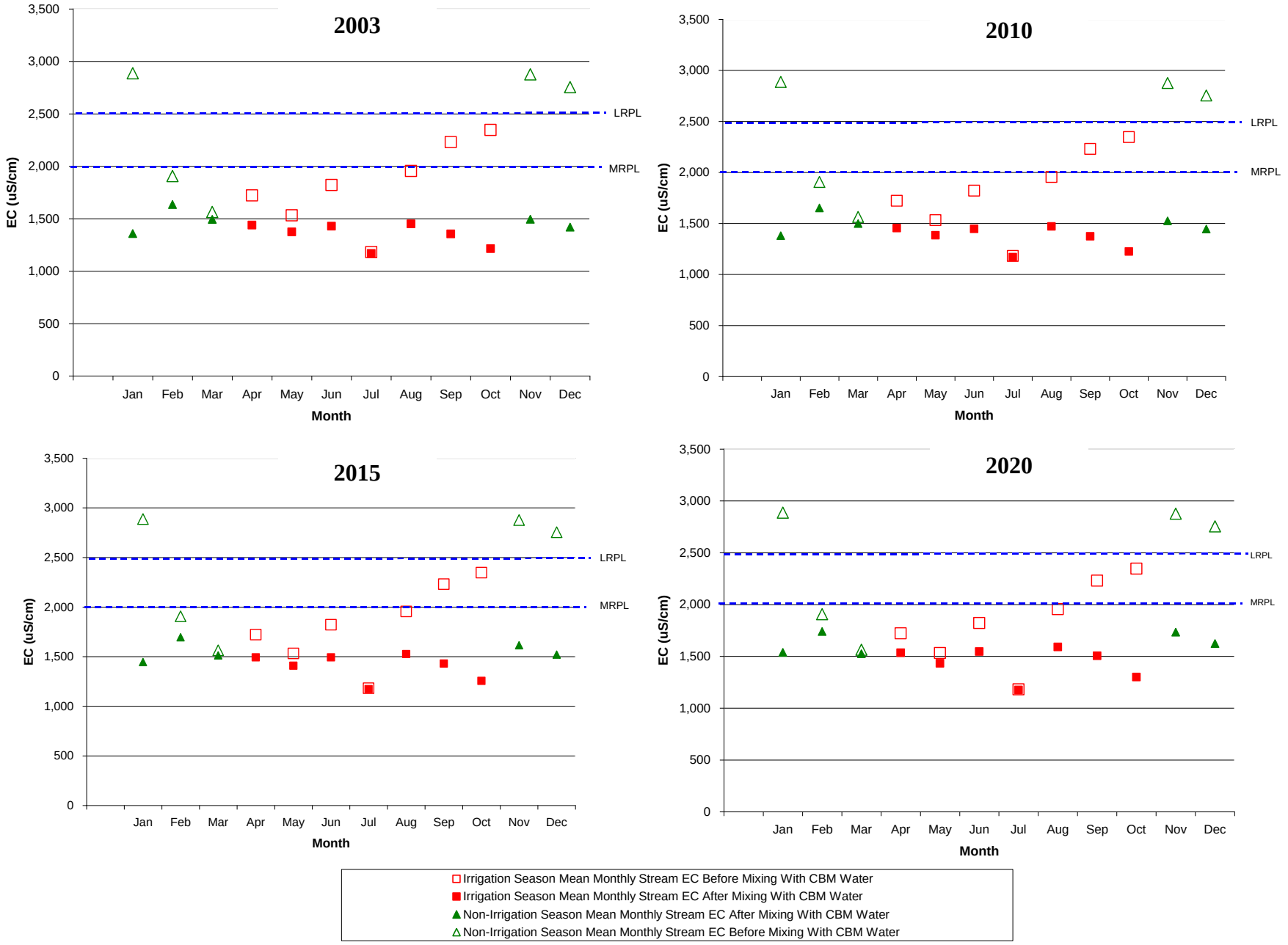

Figure 3.4-2
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Belle Fourche River below Moorcroft, WY (06426500)

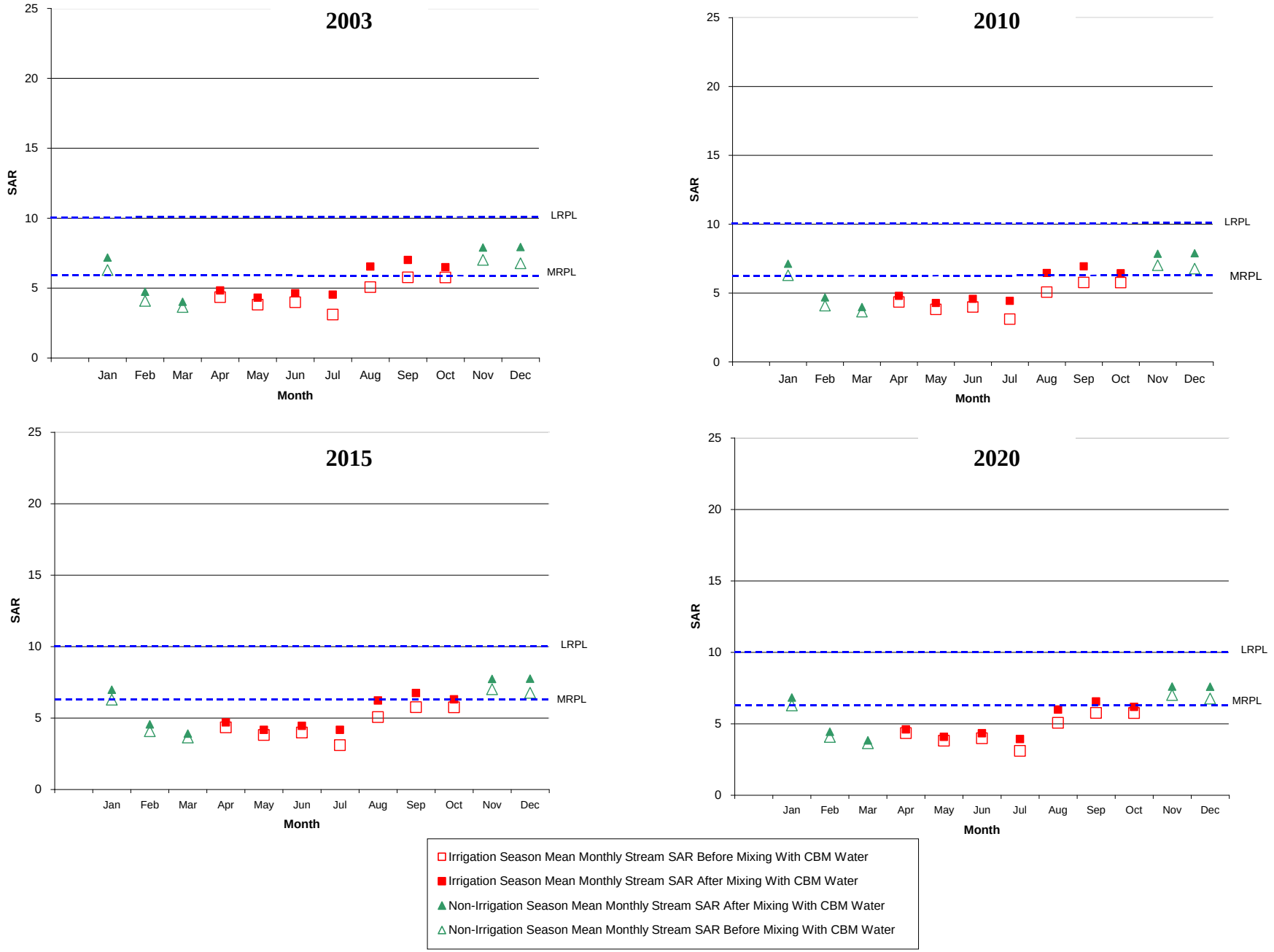

Figure 3.4-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Belle Fourche River below Moorcroft, WY (06426500)

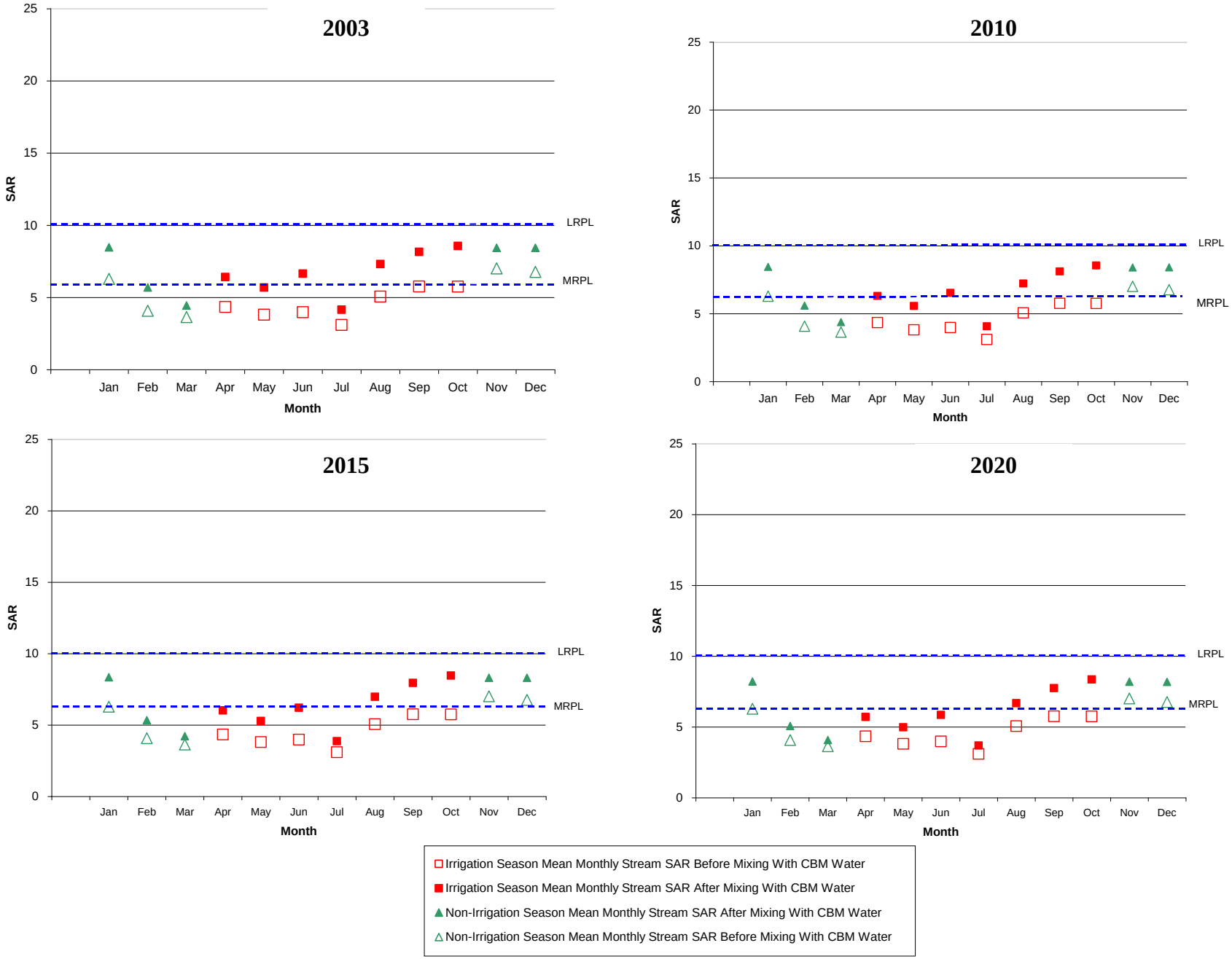

Figure 3.4-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Belle Fourche River below Moorcroft, WY (06426500)

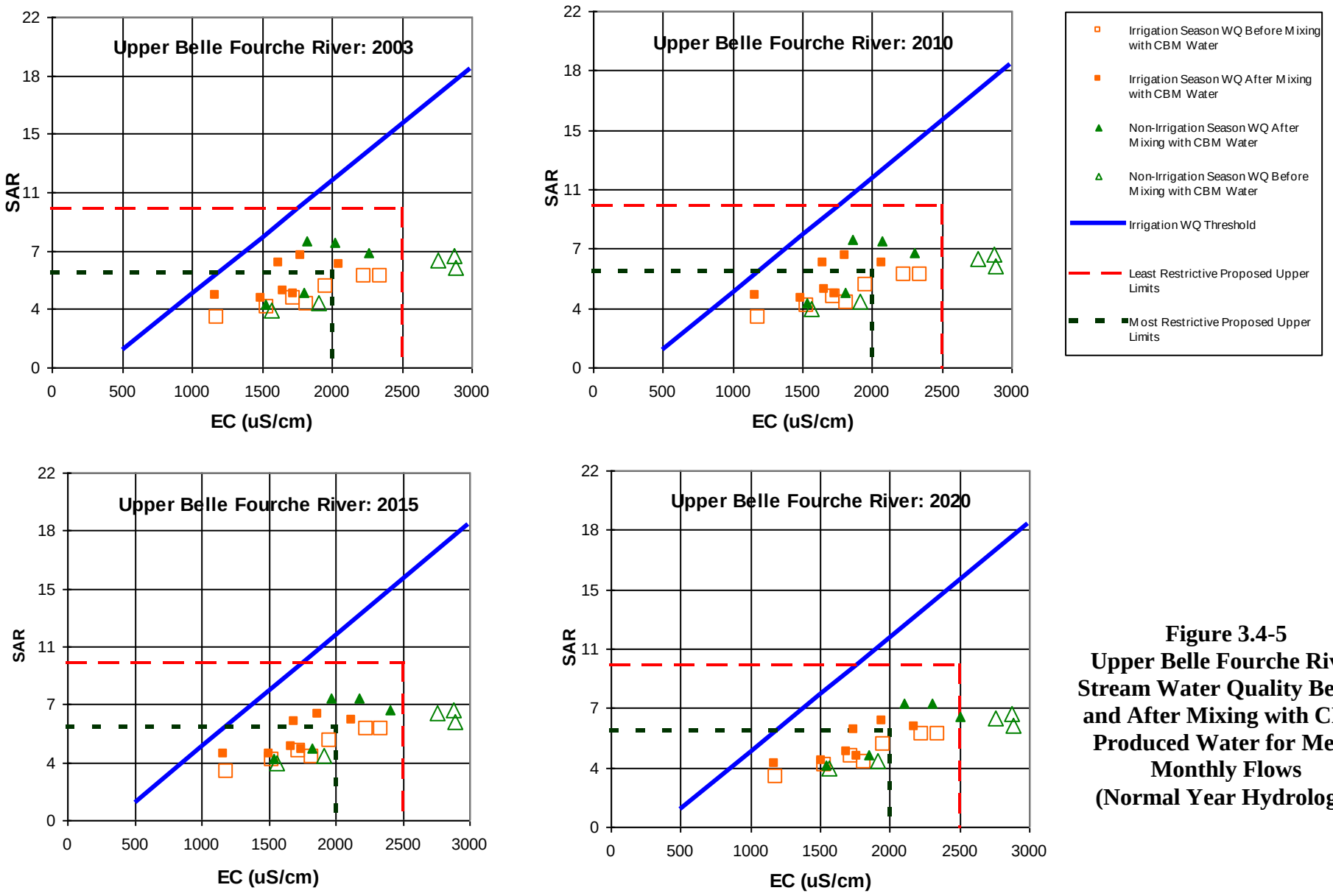

Figure 3.4-5
Upper Belle Fourche River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Normal Year Hydrology)

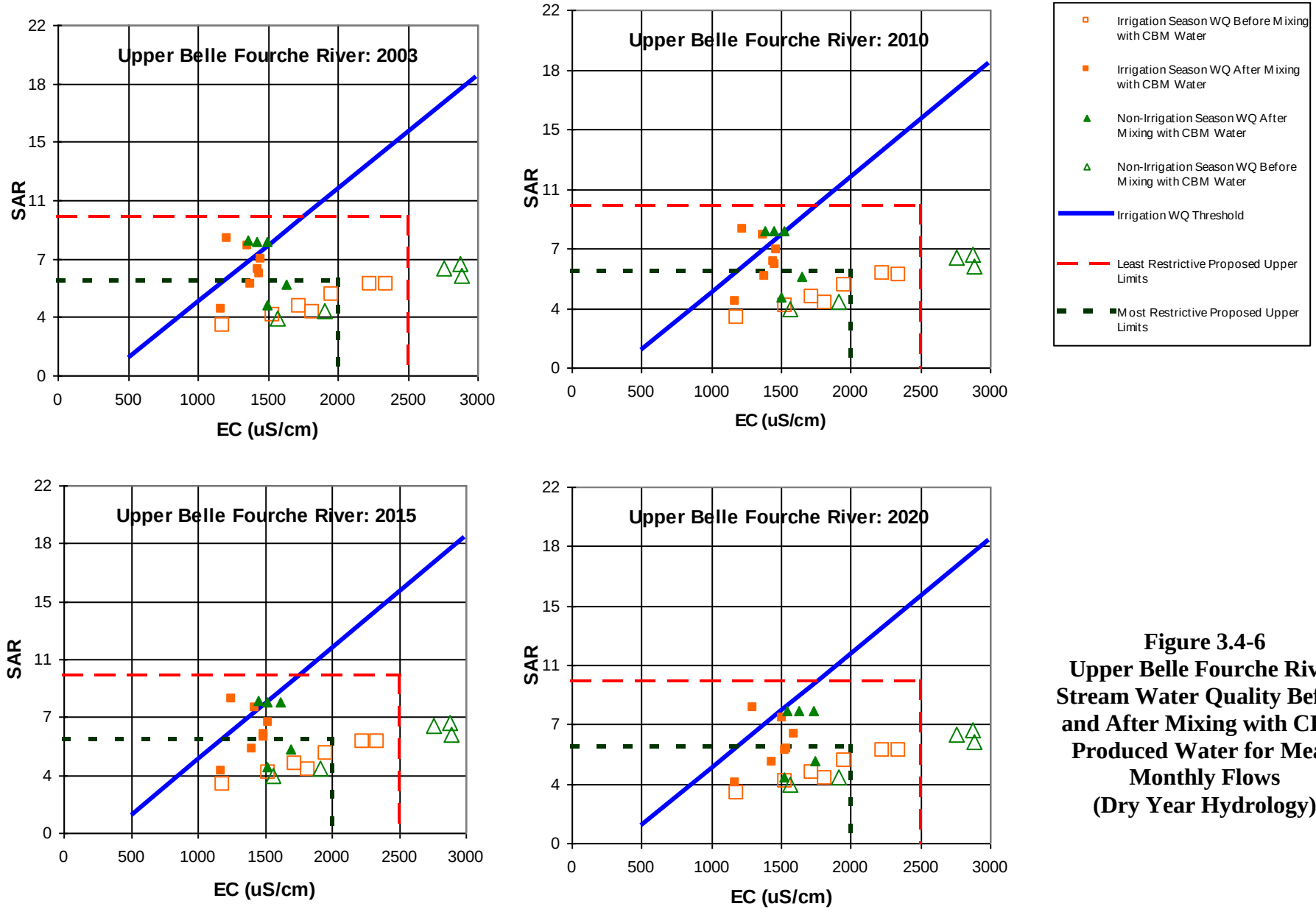

Figure 3.4-6
Upper Belle Fourche River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Dry Year Hydrology)

- Before Mixing. Same as the current conditions (2003) presented in Section 3.4.1.

- Following Mixing . The resultant EC values decrease sufficiently to meet both the LRPL and MRPL for dry-year conditions and exceed the MRPL during October, November and January for the normal year. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the months of February, March, May and July and are less than the LRPL for the dry year. For the normal year, the resultant SAR values exceed the MRPL from August through January and are less than the LRPL for all months.

- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and is considered unsuitable for the months of August, September and October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.4.3 Upper Belle Fourche River: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.4-1, 3.4-2, 3.4-3, 3.4-4, 3.4-5 and 3.4-6**. For RFD Scenario 2015, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.4.1.

- Following Mixing . The resultant EC values decrease sufficiently to meet both the LRPL and MRPL for dry-year conditions and exceed the MRPL during October, November and January for the normal year. The resultant SAR values increase and exceed the MRPL for SAR with the exception of the months of February, March, April, May and July and are less than the LRPL for the dry year. For the normal year, the resultant SAR values exceed the MRPL from August through January and are less than the LRPL for all months.

- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the months of September and October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG

production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.4.4 Upper Belle Fourche River: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are also presented in Figures **3.4-1, 3.4-2, 3.4-3, 3.4-4, 3.4-5 and 3.4-6**. For RFD Scenario 2020, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.4.1.
- Following Mixing . The resultant EC values decrease sufficiently to meet both the LRPL and MRPL for dry-year conditions and exceed the MRPL from October through January for the normal year. The resultant SAR values increase and exceed the MRPL for SAR from August through January and are less than the LRPL for the dry year. For the normal year, the resultant SAR values exceed the MRPL from September through January and are less than the LRPL for all months.
- Ayers and Westcot Diagram. For the dry-year conditions, the data indicate a reduction in infiltration following mixing with CBNG production water, and may be unsuitable for the month of October during the irrigation season. Under normal-year conditions, only a minor decrease in infiltration is realized following mixing with CBNG production water; overall, the data indicates that the mixed water is suitable for irrigation during a normal year.

3.5 Upper Cheyenne River

Results of the impacts to water quality in the Upper Cheyenne River subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.5-1**. **Table 3.5-1** reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year and normal-year hydrologic conditions. As stated previously, the information in **Table 3.5-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow in the Upper Cheyenne River for each RFD scenario. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The peak CBNG discharge in the watershed is realized for the current conditions (i.e., 2003) and RFD Scenario 2010 when 0.84 cfs is conveyed into the Upper Cheyenne River. The quantity of water discharged into the Upper Cheyenne River would be less in the other RFD scenarios and would consequently result in a reduction in impacts to the existing water quality. For the dry-year hydrologic conditions for RFD Scenario 2010, **Table 3.5-1** illustrates the impacts associated with mixing 0.8 cfs (occurring in the month of August) of streamflow in the Upper Cheyenne River with 0.84 cfs of CBNG well discharge water on both SAR and EC. After the flows mix, the resulting EC would decrease, whereas the SAR is similar compared to existing stream water quality conditions (see water quality input data in Appendix B). The combined streamflow of approximately 1.6 cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to meet the LRPL and the MRPL for both EC and SAR.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs. It should be noted that the minimum mean monthly flow for the normal year exceeds the minimum mean monthly flow for the dry year. As indicated in **Appendix B** and presented in the technical memorandum in **Appendix D**, the total flow in the Upper Cheyenne River is much less during the dry year, however, the minimum monthly flow (occurring in August) during the dry year is slightly larger than the minimum monthly flow (occurring in December) of the normal year.

Table 3.5-1 Surface Water Impact Analysis of the Upper Cheyenne River Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	0.77	7.39	3405	1.57	7.50	2144
2010	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.57	7.50	2144
2015	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.47	7.50	2226
2020	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.37	7.49	2321
Dry Year										
2003	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	0.82	4.80	2271	1.62	6.20	1457
2010	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.62	6.20	1457
2015	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.52	6.11	1492
2020	10[(1)]	2000[(1)]	10[(1)]	2500[(1)]	---	---	---	1.42	6.00	1531

[(1)] Wyoming DEQ

3.5.1 Upper Cheyenne River: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.5-1, 3.5-2, 3.5-3, 3.5-4, 3.5-5 and 3.5-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For current conditions (2003), the observations presented below are based on the information presented in these figures.

- Before Mixing. Mean monthly EC values in the Upper Cheyenne River currently exceed the MRPL for all months with the exception of August and exceed the LRPL from October through June for both the dry year and normal year. Mean monthly values for SAR currently are less than the MRPL and LRPL for both hydrologic conditions.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of August in the normal year and both July and August in the dry year. EC values exceed the LRPL during November and January through June for the normal year along with October for the dry year. The resultant SAR values are similar and remain less than the MRPL and LRPL for both hydrologic conditions.
- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a minor reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.5.2 Upper Cheyenne River: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.5-1, 3.5-2, 3.5-3, 3.5-4, 3.5-5 and 3.5-6**. The observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.5.1.
- Following Mixing . The contribution of CBNG production water in RFD Scenario 2010 is the same as the current conditions (2003). Consequently, the results are the same as those presented in Section 3.5.1.

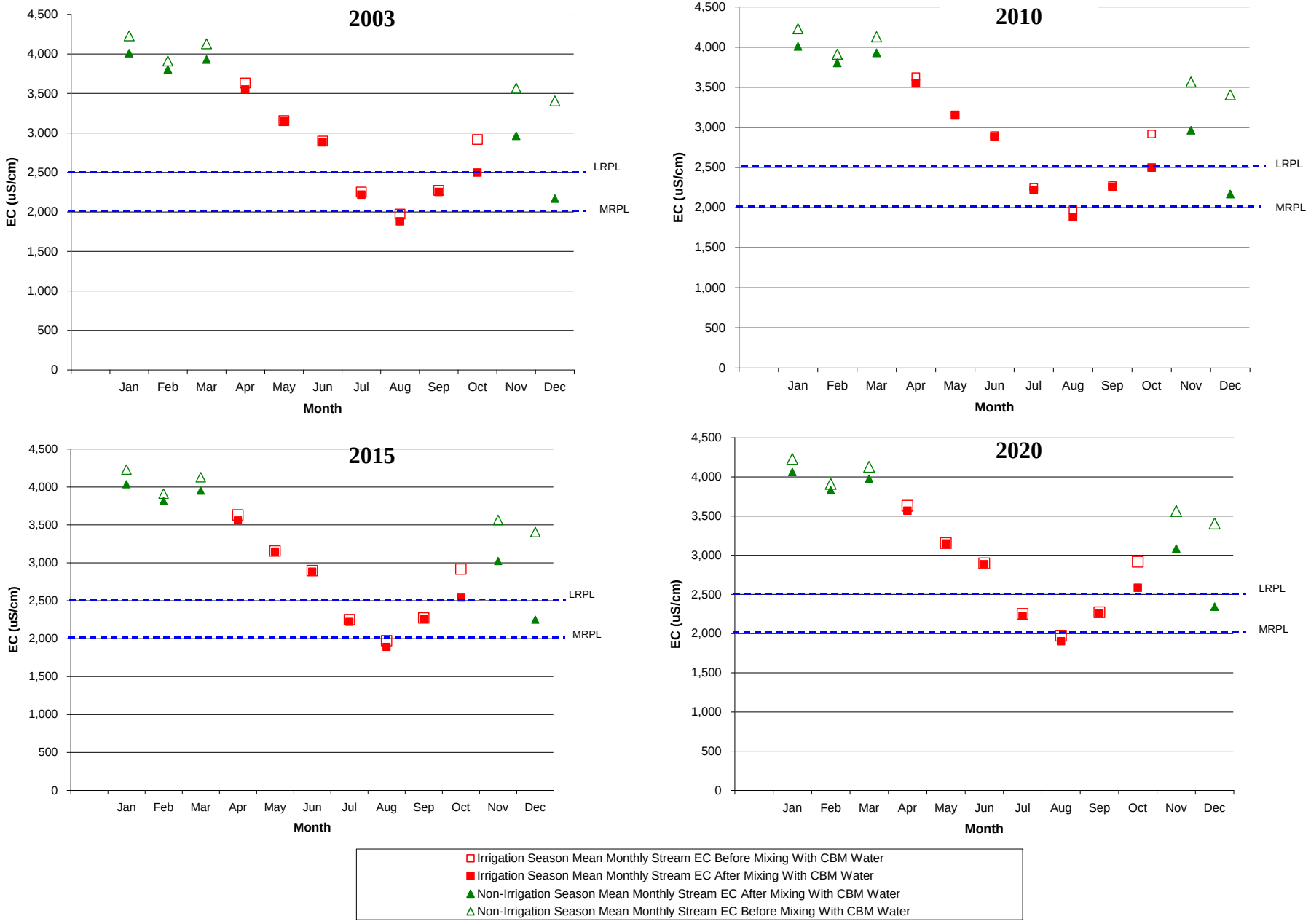

Figure 3.5-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Cheyenne River near Spencer, WY (06386500)

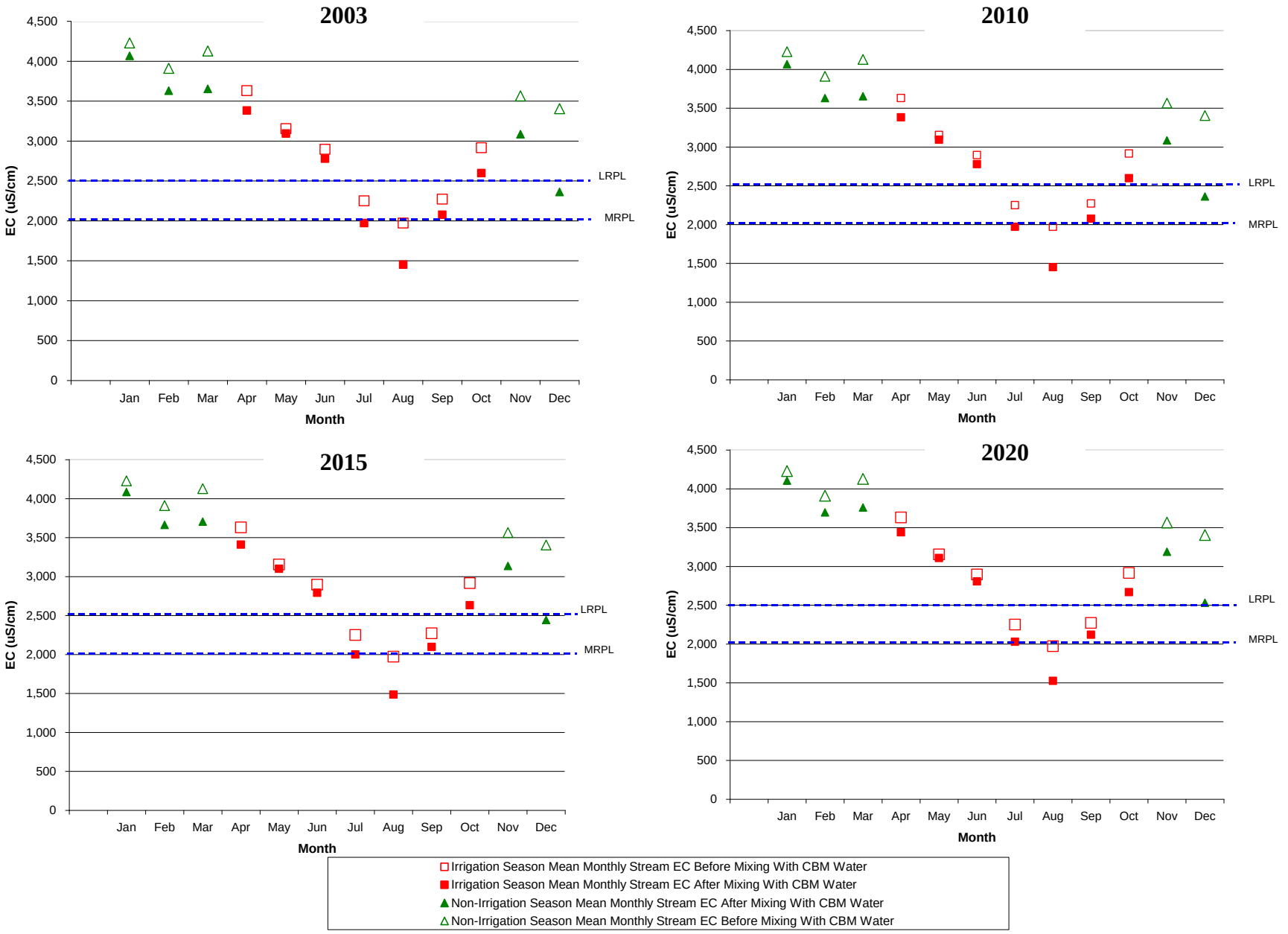

Figure 3.5-2
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Cheyenne River near Spencer, WY (06386500)

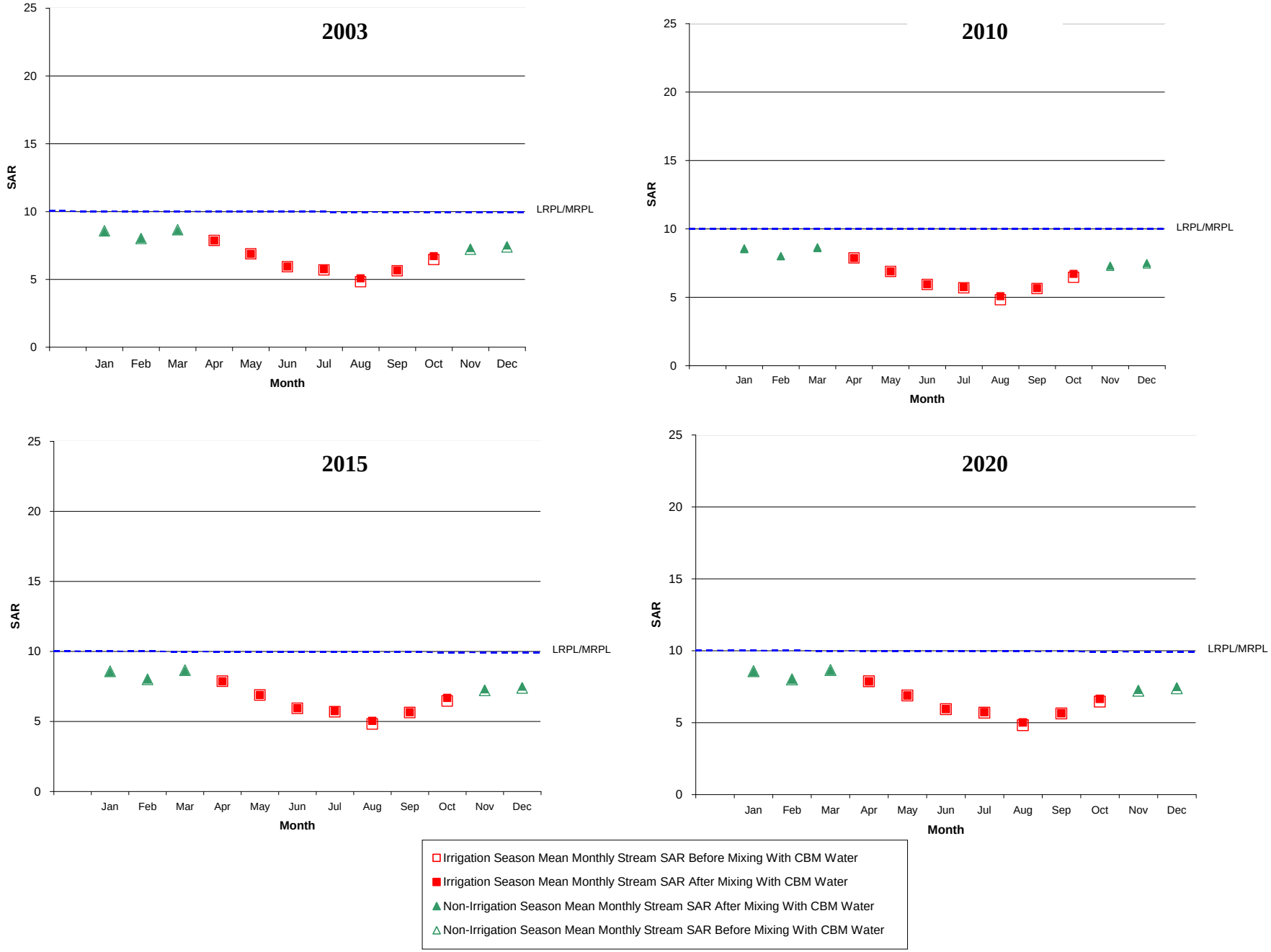

Figure 3.5-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Cheyenne River near Spencer, WY (06386500)

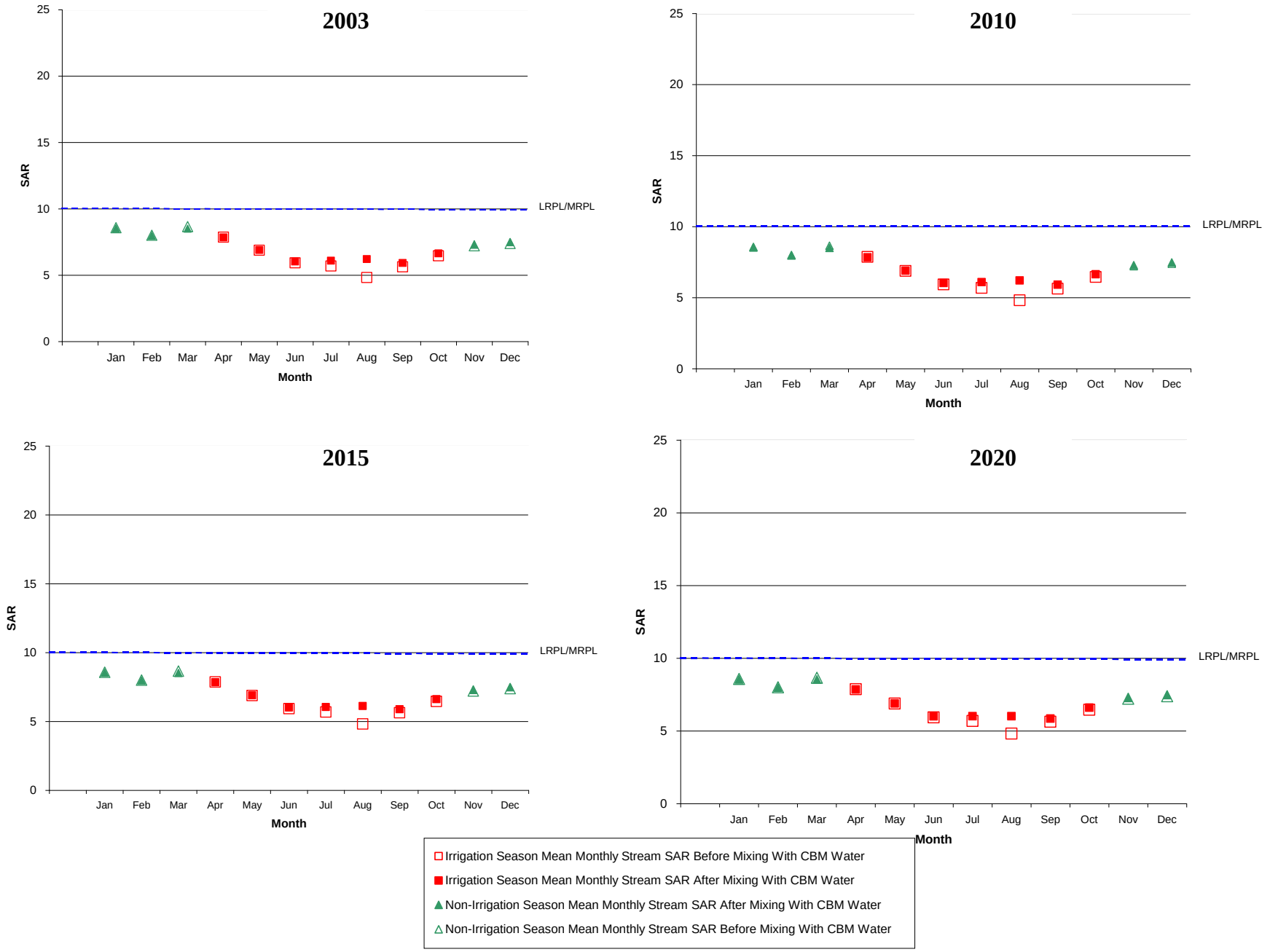

Figure 3.5-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Cheyenne River near Spencer, WY (06386500)

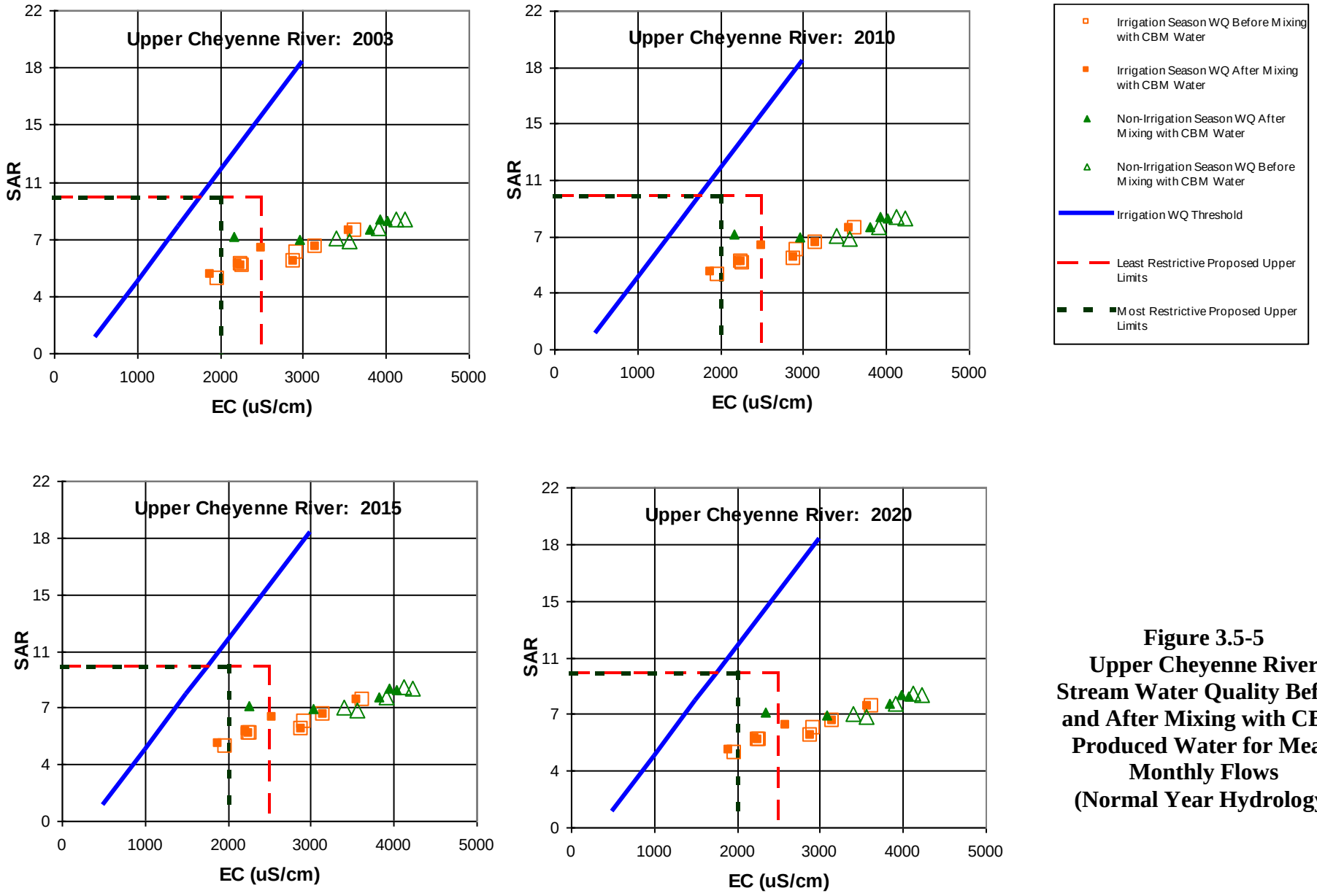

Figure 3.5-5
Upper Cheyenne River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Normal Year Hydrology)

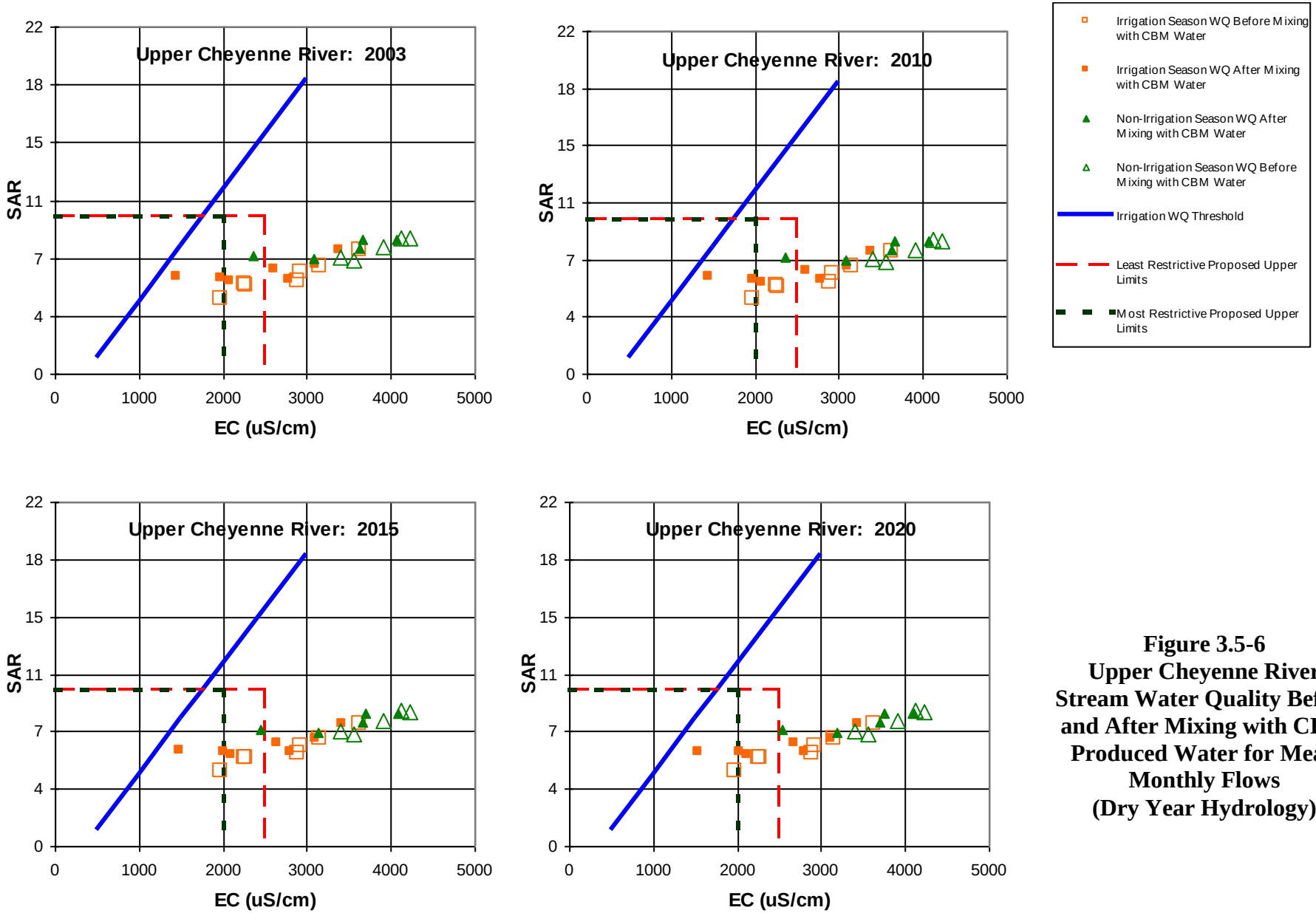

Figure 3.5-6
Upper Cheyenne River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Dry Year Hydrology)

- Ayers and Westcot Diagram. The contribution of CBNG production water in RFD Scenario 2010 is the same as the current conditions (2003). Consequently, the results are the same as those presented in Section 3.5.1.

3.5.3 Upper Cheyenne River: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.5-1, 3.5-2, 3.5-3, 3.5-4, 3.5-5 and 3.5-6**. The observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.5.1.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of August in the normal year and both July and August in the dry year. EC values exceed the LRPL during October, November and January through June for both the dry year and normal year. The resultant SAR values are similar and remain less than the MRPL and LRPL for both hydrologic conditions.
- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a minor reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.5.4 Upper Cheyenne River: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are presented in Figures **3.5-1, 3.5-2, 3.5-3, 3.5-4, 3.5-5 and 3.5-6**. The observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.5.1.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of August in the normal year and dry year. EC values exceed the LRPL during October, November and January through June for the normal year along with December for the dry year. The resultant SAR values are similar and remain less than the MRPL and LRPL for both hydrologic conditions.

- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a minor reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.6 Upper Powder River

Results of the impacts to water quality in the Upper Powder River subwatershed under the current condition and each of the three future RFD scenarios are presented in **Table 3.6-1**. **Table 3.6-1** reflects the results of the impact assessment at minimum mean monthly flow for both the dry-year and normal-year hydrologic conditions. As stated previously, the information in **Table 3.6-1** is obtained from the results of the spreadsheet model documented in Appendix C and specifically evaluates the impact analysis for the minimum mean monthly flow in the Upper Powder River for each RFD scenario. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality initially focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The peak CBNG discharge in the watershed is realized for the current conditions (i.e., 2003) and RFD Scenario 2015 when 9.6 cfs is conveyed into the Upper Powder River. The quantity of water discharged into the Upper Powder River would be less in the other RFD scenarios and would consequently result in a reduction in impacts to the existing water quality. For the dry-year hydrologic conditions for RFD Scenario 2015, **Table 3.6-1** illustrates the impacts associated with mixing 38.5 cfs (occurring in the month of September) of streamflow in the Upper Powder River with 9.6 cfs of CBNG well discharge water on both SAR and EC. After the flows mix, the resulting EC slightly decreases, whereas the SAR is slightly increased compared to existing stream water quality conditions (see water quality input data in Appendix B). The combined streamflow of approximately 48.2 cfs reflects a resultant water quality, associated with the minimum mean monthly flow, that appears to exceed the LRPL and the MRPL for both EC and SAR.

The existing stream water quality data identify the minimum mean monthly flow (2003) and corresponding EC and SAR data for both the normal and dry years. Typically, the month in which the minimum flows occur varies from the normal and dry years, and generally reflects a decrease in flow. The baseline (2003) EC and SAR data may demonstrate an increase or decrease from the normal year to dry year depending on the month in which the minimum flow occurs.

Table 3.6-1 Surface Water Impact Analysis of the Upper Powder River Subwatershed

Scenario	MRPL		LRPL		Existing Stream Water Quality at Minimum Mean Monthly Flow			Resulting Stream Water Quality at Minimum Mean Monthly Flow		
	SAR	EC (uS/cm)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)	Flow (cfs)	SAR	EC (uS/cm)
Normal Year										
2003	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	103.61	6.40	2482	105.91	6.75	2475
2010	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	111.61	7.56	2460
2015	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	113.21	7.77	2456
2020	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	112.61	7.69	2458
Dry Year										
2003	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	38.51	7.83	3400	40.87	8.66	3331
2010	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	46.57	10.36	3190
2015	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	48.17	10.77	3157
2020	5[(1)]	2000[(1)]	9.75[(1)]	2500[(1)]	---	---	---	47.57	10.62	3169

[(1)] Montana DEQ

3.6.1 Upper Powder River: Current Conditions (2003)

The results of the water quality impact assessment under current conditions and all RFD Scenarios are presented in **Figures 3.6-1, 3.6-2, 3.6-3, 3.6-4, 3.6-5 and 3.6-6**. The information in these figures reflects the results of the impact assessment for all monthly flows for both the dry-year and normal-year hydrologic conditions. For the current conditions (2003), the observations presented below are based on the information presented in these figures.

- Before Mixing. Mean monthly EC values in the Upper Powder River currently exceed the MRPL for all months with the exception of May and June and exceed the LRPL from July through December for both the dry year and normal year. Mean monthly values for SAR currently exceed the MRPL for all months except May and June and meet the LRPL for both hydrologic conditions.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of May and June for both the normal year and dry year. EC values continue to exceed the LRPL from July through December for both the dry year and normal year. The resultant SAR values are increased and exceed the MRPL for all months for the dry year, and all months with the exception of May and June for the normal year. SAR values meet the LRPL for both hydrologic conditions.
- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a very slight reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

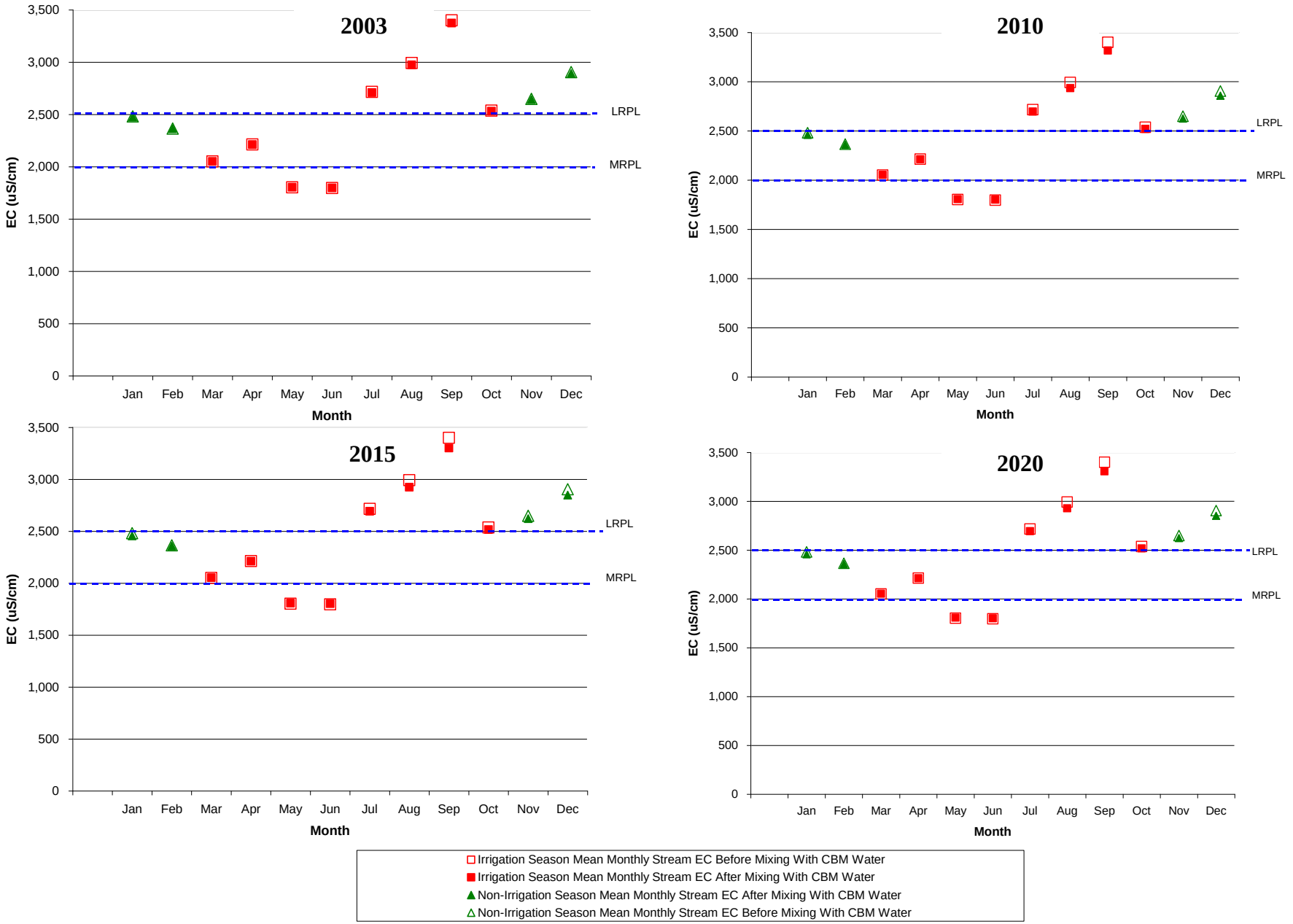

Figure 3.6-1
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Upper Powder River at Arvada, WY (06317000)

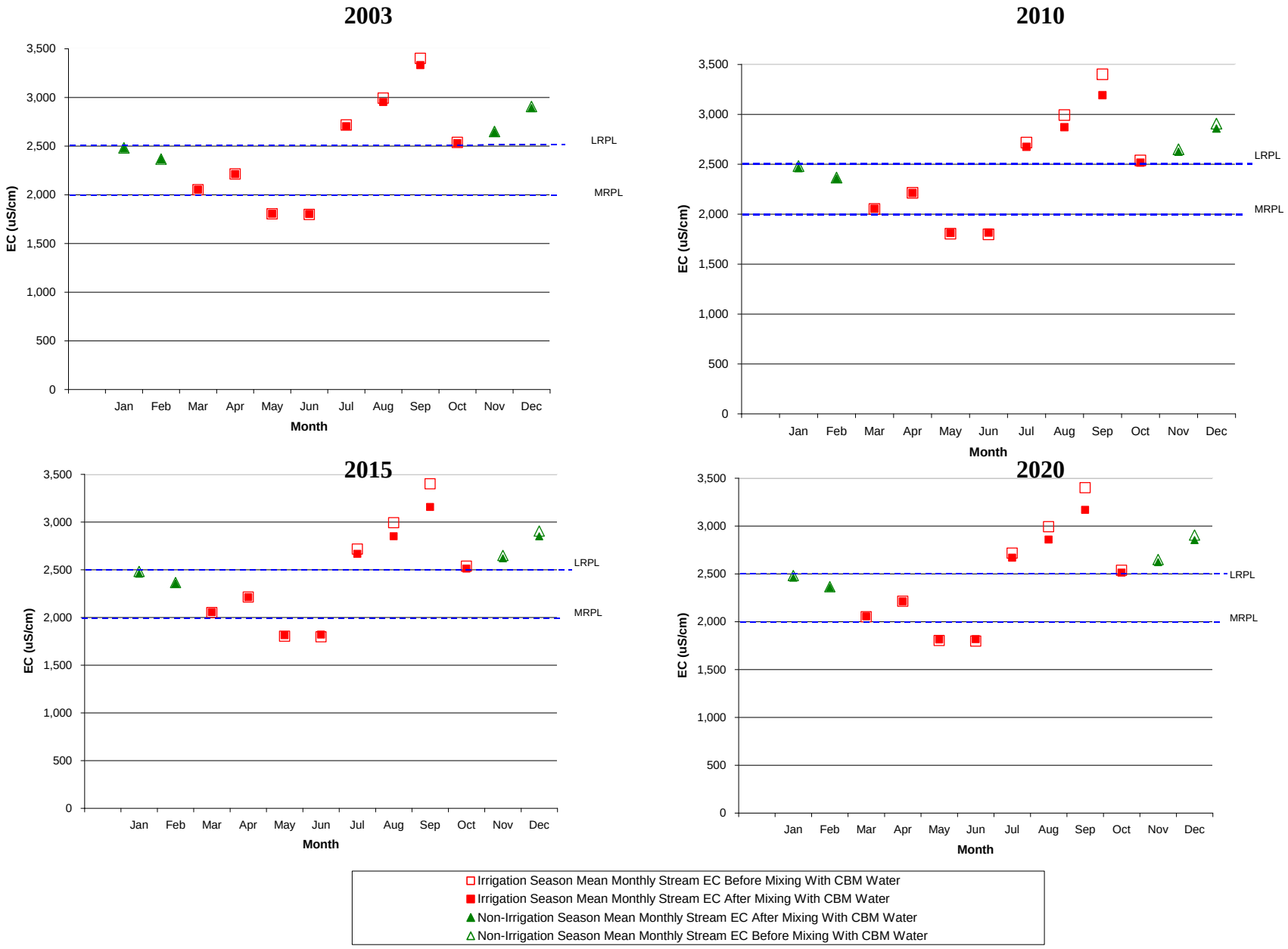

Figure 3.6-2
Stream EC Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Upper Powder River at Arvada, WY (06317000)

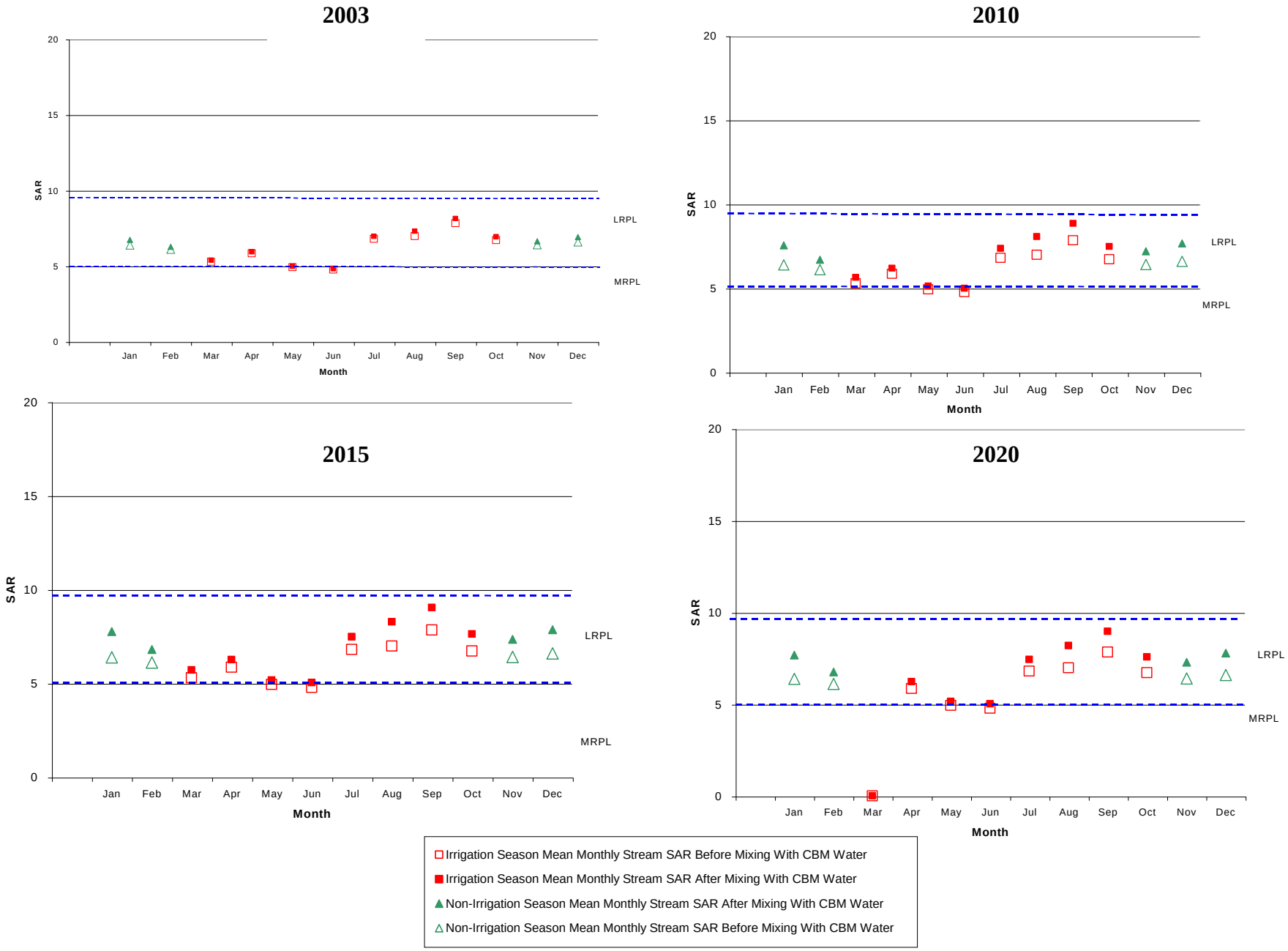

Figure 3.6-3
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Normal Year Hydrology
Upper Powder River at Arvada, WY (06317000)

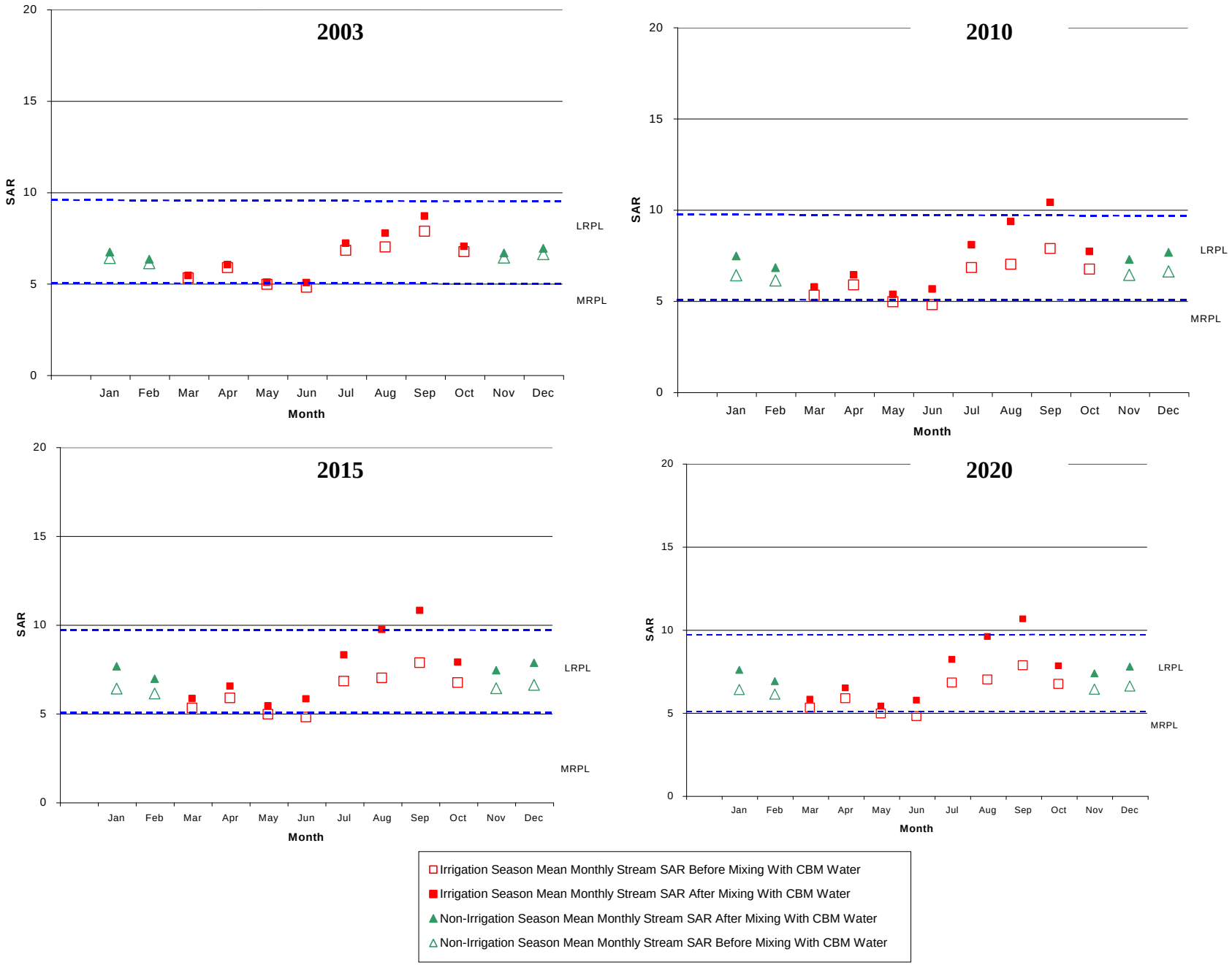

Figure 3.6-4
Stream SAR Before and After Mixing with CBM Produced Water
for Mean Monthly Flows – Dry Year Hydrology
Upper Powder River at Arvada, WY (06317000)

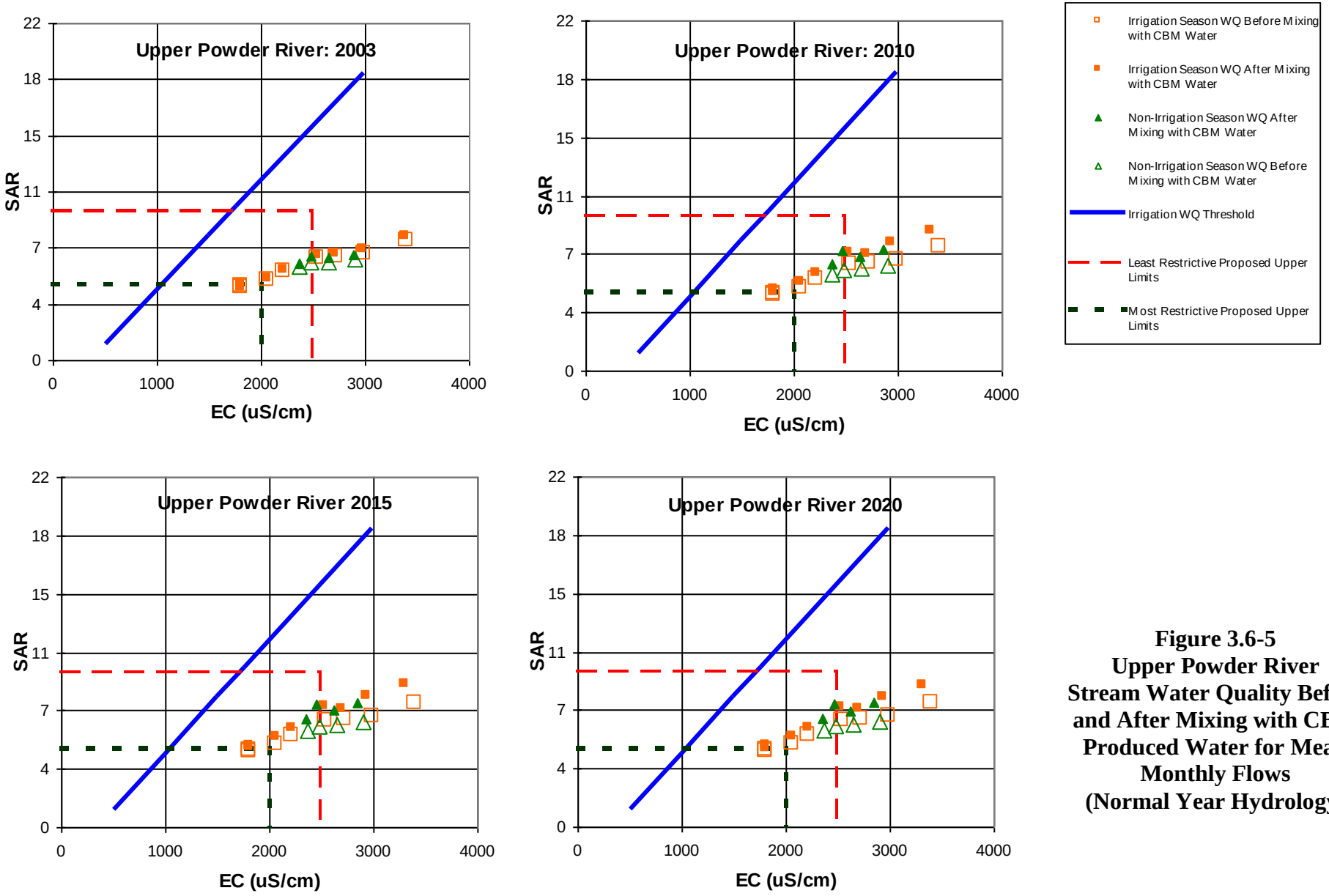

Figure 3.6-5
Upper Powder River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Normal Year Hydrology)

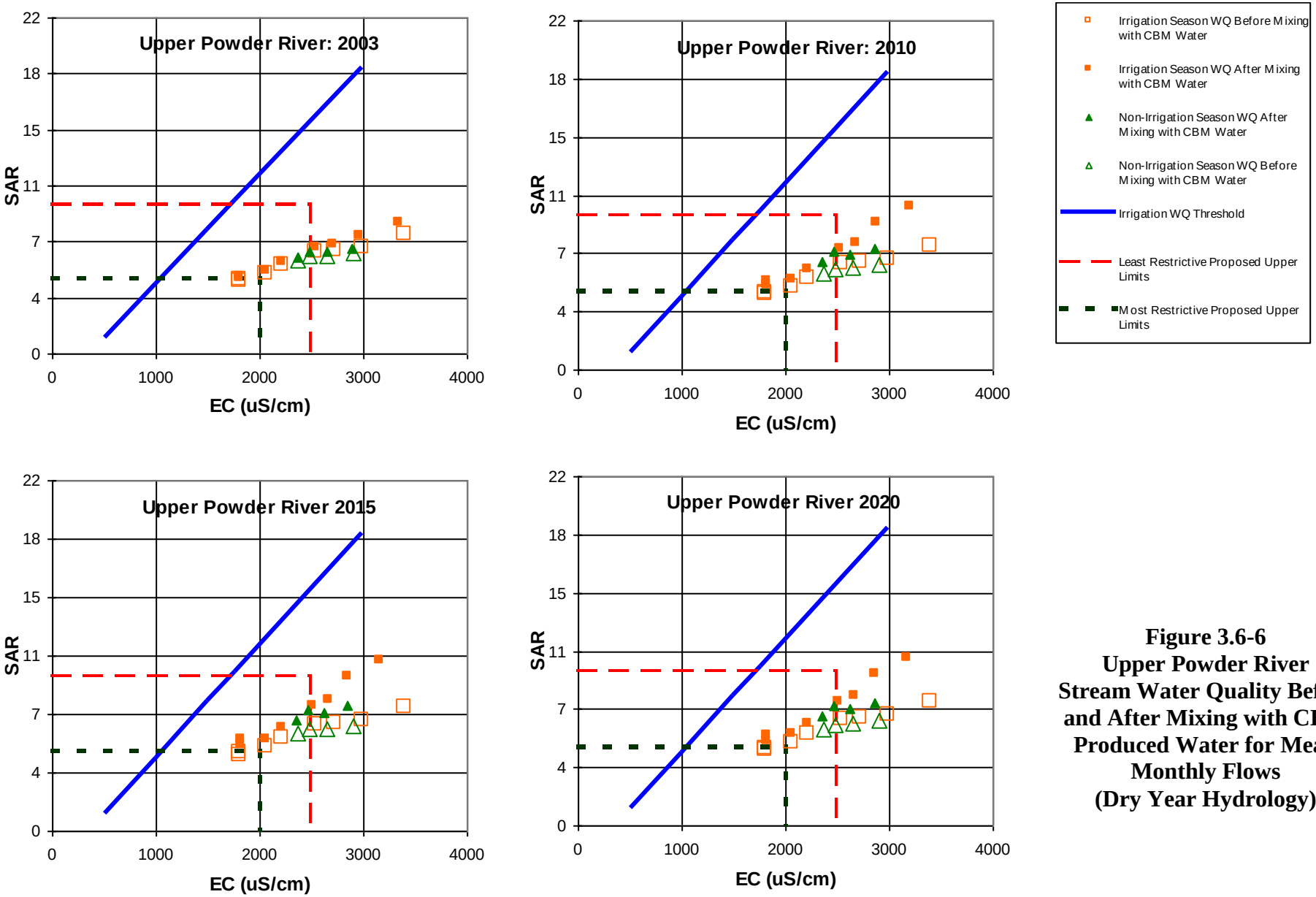

Figure 3.6-6
Upper Powder River Stream Water Quality Before and After Mixing with CBM Produced Water for Mean Monthly Flows (Dry Year Hydrology)

3.6.2 Upper Powder River: RFD Scenario 2010 Conditions

The results of the water quality impact assessment under RFD Scenario 2010 conditions are also presented in **Figures 3.6-1, 3.6-2, 3.6-3, 3.6-4, 3.6-5 and 3.6-6**. For RFD Scenario 2010, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.6.1.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of May and June for both the normal year and dry year. EC values continue to exceed the LRPL from July through December for both the dry year and normal year. The resultant SAR values are increased and exceed the MRPL for all months for the dry year, and all months with the exception of June for the normal year. SAR values meet the LRPL with the exception of the month of September for the dry-year condition.
- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a slight reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.6.3 Upper Powder River: RFD Scenario 2015 Conditions

The results of the water quality impact assessment under RFD Scenario 2015 conditions are also presented in **Figures 3.6-1, 3.6-2, 3.6-3, 3.6-4, 3.6-5 and 3.6-6**. For RFD Scenario 2015, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.6.1.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of May and June for both the normal year and dry year. EC values continue to exceed the LRPL from July through December for both the dry year and normal year. The resultant SAR values are increased and exceed the MRPL for all months for the dry year, and all months with the exception of June for the normal year. SAR values meet the LRPL with the exception of the month of September for the dry-year condition.

- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a slight reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.6.4 Upper Powder River: RFD Scenario 2020 Conditions

The results of the water quality impact assessment under RFD Scenario 2020 conditions are also presented in **Figures 3.6-1, 3.6-2, 3.6-3, 3.6-4, 3.6-5 and 3.6-6**. For RFD Scenario 2020, the observations presented below are based on the information presented in these figures.

- Before Mixing. Same as the current conditions (2003) presented in Section 3.6.1.
- Following Mixing . The resultant EC values slightly decrease but continue to exceed the MRPL for all months with the exception of May and June for both the normal year and dry year. EC values continue to exceed the LRPL from July through December for both the dry year and normal year. The resultant SAR values are increased and exceed the MRPL for all months for both the dry and normal year. SAR values meet the LRPL with the exception of the month of September for the dry-year condition.
- Ayers and Westcot Diagram. For both the normal-year and dry-year conditions, the data indicate a slight reduction in infiltration following mixing with CBNG production water. Overall, the data indicates that the mixed water is suitable for irrigation during both hydrologic conditions.

3.7 Sensitivity Analysis

A sensitivity analysis was conducted on the CBNG well discharge data (EC and SAR) provided by the Wyoming DEQ/WQD. The approach to the sensitivity analysis is described below.

- A statistical evaluation was conducted to determine the mean value and 95% confidence intervals associated with the monthly data for each EC and SAR data set.
- The spreadsheet model (water quality mixing) was utilized and iterated with the mean value and the upper and lower values associated within the 95% confidence interval for the CBNG discharge data to determine the mixed water quality.

- The difference (as a percentage) was computed between the mixed "mean" water quality and the water quality predicted for the upper and lower values within the 95% confidence interval.

The results of the sensitivity analysis are presented in Appendix C. In general, the results are summarized below.

- In the Dry Fork Cheyenne River, the maximum difference in the predicted values for EC was determined to be 0.99%. The maximum difference in predicted values for SAR was determined to be approximately 9.1%.
- In the Little Powder River, the maximum difference in the predicted values for EC was determined to be 0.87%. The maximum difference in predicted values for SAR was determined to be approximately 4.9%.
- In the Upper Cheyenne River, the maximum difference in the predicted values for EC was determined to be 0.71%. The maximum difference in predicted values for SAR was determined to be approximately 6.5%.
- In the Upper Powder River, the maximum difference in the predicted values for EC was determined to be 0.12%. The maximum difference in predicted values for SAR was determined to be approximately 1.8%.
- In the Upper Belle Fourche River, the maximum difference in the predicted values for EC was determined to be 0.57%. The maximum difference in predicted values for SAR was determined to be approximately 4.2%.
- In Antelope Creek, the maximum difference in the predicted values for EC was determined to be 2.1%. The maximum difference in predicted values for SAR was determined to be approximately 10.6%.

3.8 Summary

The impacts to water quality on the receiving drainages assumed two hydrologic conditions; dry-year conditions and normal-year conditions. The impact analysis was conducted using monthly flows and comparatively evaluated the water quality parameters (SAR and EC) of the receiving drainage before and after mixing with discharge water generated by the CBNG wells within the watershed. In general, the water discharged from the CBNG wells reflected increased levels of SAR and reduced levels of EC compared to the water quality of the receiving drainages. Impacts

to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality also focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The results of the water quality analyses are summarized in **Table 3.8-1** and **Table 3.8-2**. Several observations can be made regarding the overall effects of mixing CBNG well production water with surface water within the study area. These general observations are discussed in the following paragraphs.

3.8.1 Current Surface Water Quality Conditions

With respect to the Most Restrictive Proposed Limit (MRPL) and the Least Restrictive Proposed Limit (LRPL) for the impact analysis, several of the surface water sources currently (2003, prior to mixing) exceed the MRPL during many months of the years. Specific observations related to the water quality of the surface water sources are listed below.

- The surface water in the Upper Powder River exceeds the MRPL for both EC and SAR throughout the majority of the year. Levels of SAR are less than the LRPL while EC values generally exceed the LRPL the latter half of the year (July through December).
- The surface water in both Antelope Creek and the Dry Fork Cheyenne River exceeds the MRPL for EC during the low-flow months from September through February. Levels of EC are typically less than the LRPL. The SAR values are relatively low and do not exceed the MRPL.
- The surface water in the Little Powder River exceeds the MRPL for EC and SAR throughout the majority of the year and exceeds the LRPL for EC during the low flow months of August, September and November through January. SAR levels remain below the LRPL throughout the year.
- The surface water in the Upper Cheyenne River exceeds the MRPL for EC for eleven months of the year and exceeds the LRPL nine months of the year. The surface water does not exceed the MRPL for SAR.
- The surface water in the Upper Belle Fourche River exceeds the MRPL for EC during the low-flow months from September through January. Levels of EC are less than the LRPL with the exception of November through January. The SAR values are relatively low but tend to exceed the MRPL from November through January while meeting the LRPL throughout the year.

Table 3.8-1 Water Quality Results (Normal Year)

Item	Existing Condition (Before Mixing)	2003 (After Mixing)	2010 (After Mixing)	2015 (After Mixing)	2020 (After Mixing)
Antelope Creek					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increased	Increased	Increased	Increased
Irrigation[1]	Suitable	Suitable	Suitable	Suitable (Except Oct)	Suitable (Except Oct)
MRPL	Exceeds EC (Sept-Feb)	OK	OK	OK	OK
LRPL	OK	OK	OK	OK	OK
Upper Belle Fourche River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slightly Increased	Slightly Increased	Slightly Increased	Slightly Increased
Irrigation[1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Sept-Jan) Exceeds SAR (Nov-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Oct-Jan) Exceeds SAR (Sept-Jan)
LRPL	Exceeds EC (Nov-Jan)	OK	OK	OK	OK
Upper Cheyenne River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	≅ CBNG Discharge	Same	Same	Same	Same
Irrigation[1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)
LRPL	Exceeds EC (Oct-June)	Exceeds EC (Jan-June, Nov)	Exceeds EC (Jan-June, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)
Upper Powder River					
EC	≅ CBNG Discharge	Slight Decrease	Slight Decrease	Slight Decrease	Slight Decrease
SAR	< CBNG Discharge	Slight Increase	Slight Increase	Slight Increase	Slight Increase
Irrigation[1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR (Exc. June)	Exceeds EC (July-Apr) Exceeds SAR (Exc. June)	Exceeds EC (July-Apr) Exceeds SAR (All Year)
LRPL	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)
Little Powder River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slight Increase	Slight Increase	Slight Increase	Slight Increase
Irrigation[1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Mar) Exceeds SAR (Except Mar, May)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)
LRPL	Exceeds EC (Aug, Sept, Nov-Jan)	Exceeds EC (Jan, Aug)	Exceeds EC (Jan)	Exceeds EC (Jan)	Exceeds EC (Jan, Aug)
Dry Fork Cheyenne River					
EC	> CBNG Discharge	Same (No CBNG Discharge)	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Same (No CBNG Discharge)	Slight Increase	Slight Increase	Slight Increase
Irrigation[1]	Suitable	Same (No CBNG Discharge)	Suitable (Except Sept)	Suitable (Except Sept)	Suitable (Except Sept)
MRPL	Exceeds EC (June, Sept-Feb)	Same (No CBNG Discharge)	Exceeds EC (Feb, Nov)	Exceeds EC (Feb)	Exceeds EC (Feb)
LRPL	OK	OK	OK	OK	OK

1. Irrigation results reflect suitability of water for irrigation during the irrigation season

Table 3.8-2 Water Quality Results (Dry Year)

Item	Existing Condition (Before Mixing)	2003 (After Mixing)	2010 (After Mixing)	2015 (After Mixing)	2020 (After Mixing)
Antelope Creek					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increased	Increased	Increased	Increased
Irrigation [1]	Suitable	Suitable (Except June, Aug)	Unsuitable (Except July, Sep)	Unsuitable (Except July, Sep)	Unsuitable (Except July, Sep)
MRPL	Exceeds EC (Sept-Feb)	OK	OK	OK	OK
LRPL	OK	OK	OK	OK	OK
Upper Belle Fourche River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slightly Increased	Slightly Increased	Slightly Increased	Slightly Increased
Irrigation [1]	Unsuitable (Aug-Oct)	Unsuitable (Aug-Oct)	Unsuitable (Aug-Oct)	Unsuitable (Sep-Oct)	Unsuitable (Oct)
MRPL	Exceeds EC (Sept-Jan) Exceeds SAR (Nov-Jan)	OK Exceeds SAR (Exc. Feb, Mar, May, July)	OK Exceeds SAR (Exc. Feb, Mar, May, July)	OK Exceeds SAR (Exc. Feb, Mar-May, July)	OK Exceeds SAR (Aug-Jan)
LRPL	Exceeds EC (Nov-Jan)	OK	OK	OK	OK
Upper Cheyenne River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	≅ CBNG Discharge	Slight Increase (July-Sept)	Slight Increase (July-Sept)	Slight Increase (July-Sept)	Slight Increase (July-Sept)
Irrigation [1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except Aug)
LRPL	Exceeds EC (Oct-June)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Oct-June)
Upper Powder River					
EC	≅ CBNG Discharge	Same	Slightly Decreases (Aug, Sept)	Slightly Decreases (Aug, Sept)	Slightly Decreases (Aug, Sept)
SAR	< CBNG Discharge	Slight Increase	Increased	Increased	Increased
Irrigation [1]	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR
LRPL	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec) Exceeds SAR (Sept)	Exceeds EC (July-Dec) Exceeds SAR (Sept)	Exceeds EC (July-Dec) Exceeds SAR (Sept)
Little Powder River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increase	Increase	Increase	Increase
Irrigation [1]	Suitable	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)
MRPL	Exceeds EC (Except Mar) Exceeds SAR (Except Mar, May)	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR
LRPL	Exceeds EC (Aug, Sep, Nov-Jan)	Exceeds SAR (Sept)	Exceeds SAR (Sept-Jan)	Exceeds SAR (Sept-Jan)	Exceeds SAR (Sept-Nov)
Dry Fork Cheyenne River					
EC	> CBNG Discharge	Same (No CBNG Discharge)	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Same (No CBNG Discharge)	Increase	Increase	Increase
Irrigation [1]	Suitable	Same (No CBNG Discharge)	Unsuitable (June, Aug-Sep)	Unsuitable (June, Aug-Sep)	Unsuitable (June, Aug-Sep)
MRPL	Exceeds EC (June, Sept-Feb)	Same (No CBNG Discharge)	OK	OK	OK
LRPL	OK	OK	OK	OK	OK

1. Irrigation results reflect suitability of water for irrigation during the irrigation season

3.8.2 Mixed Water Quality Conditions

Specific observations related to the MRPL and LRPL *following mixing* with CBNG well production water are provided below. The observations are related to the scenario that results in the highest contribution of CBNG well production water to the surface water source thereby maximizing the potential impact associated with the CBNG well production water. These conditions are typically reflected during the dry year; consequently, the observations discussed below reflect dry-year conditions.

- The surface water in the Upper Powder River demonstrates a minimal reduction in EC and a minor increase in SAR. These results reflect the relatively small contribution of CBNG well production water to the much larger flows in Upper Powder River. EC values continue to exceed the MRPL throughout the majority of the year (July through April) and the LRPL from July through December. SAR values exceed the MRPL throughout the year while meeting the LRPL.
- The surface water in both Antelope Creek and the Dry Fork Cheyenne River reflect a reduction in EC that meets the MRPL throughout the year. Levels of SAR are increased but continue to meet the MRPL. This observation largely reflects the lack of surface water in these streams coupled with the relatively low values for EC and SAR in the CBNG well production water.
- The surface water in the Little Powder River reflects a reduction in EC but continues to exceed the MRPL for four months of the year while meeting the LRPL throughout the year. The SAR values reflect an increase and exceed the MRPL throughout the year, and exceed the LRPL from one (2003) to five (2010, 2015) months of the year.
- The surface water in the Upper Cheyenne River reflects a minor reduction in EC but continues to exceed the MRPL for ten or more months of the year and the LRPL for six or more months of the year. A minimal increase in SAR is realized and the surface water continues to meet the MRPL.
- The surface water in the Upper Belle Fourche River reflects a reduction in EC that meets the MRPL throughout the year. The SAR values reflect a slight increase and tend to exceed the MRPL six or more months of the year while meeting the LRPL throughout the year.

3.8.3 Observations Related to EC

The EC associated with the surface water sources is typically higher than the EC associated with the CBNG well production water. Consequently, the simple mixing approach utilized during the evaluation results in a reduction or improvement in EC after mixing with CBNG production water. In every instance, the most significant reduction in EC correlates to those scenarios (current conditions or RFD Scenarios) that involve the largest contribution of CBNG water to the receiving stream. This trend is amplified during time periods when surface water flows are reduced in the stream as confirmed by the results of the dry-year analysis. With the exception of the Upper Powder River, this observation was consistent for all surface water sources evaluated during this study. Within the Upper Powder River, the EC associated with the CBNG well production water was the most elevated and similar to the EC of the surface water.

3.8.4 Observations Related to SAR

The SAR associated with the surface water sources is typically lower than the SAR associated with the CBNG well production water. Similar to the evaluation of EC, the simple mixing approach utilized during the evaluation will generally result in an increase in SAR after mixing with CBNG production water. The most significant increase in SAR correlates to those scenarios (current conditions or RFD Scenarios) that involve the largest contribution of CBNG water to the receiving stream. This trend is amplified during time periods when surface water flows are reduced in the stream as confirmed by the results of the dry-year analysis. With the exception of Upper Cheyenne River, this observation was consistent for all surface water sources evaluated during this study. Within the Upper Cheyenne River, the SAR associated with the CBNG well production water was similar to the SAR of the surface water.

3.8.5 Observations Related to Irrigation Suitability

The suitability of the mixed water for irrigation purposes is also related to EC and SAR. The analysis for irrigation suitability relied solely on utilization of the Ayers Westcot Diagram. In general, the water most suitable for irrigation consists of a source with relatively low SAR and relatively high EC. Elevated SAR values may reduce permeability in clayey soils thereby reducing the rate of water infiltration. This relationship in EC and SAR is depicted in the Ayers Westcot Diagram in terms of the suitability of water sources for irrigation purposes. In those instances where the SAR is significantly increased and the EC is moderately low, the water source was considered unsuitable. This observation was specifically noted in the surface water sources associated with Antelope Creek, Dry Fork Cheyenne River, Little Power River and

Upper Belle Fourche River. For these streams, the results demonstrated adequate suitability for irrigation during the normal year conditions and unsuitable water sources during a portion, or the entire irrigation season, during the dry-year conditions. These streams also demonstrated a reduced level of EC compared to the Upper Cheyenne River and the Upper Powder River. It should be noted that the unsuitable nature of the water quality in the Dry Fork Cheyenne River is largely attributable to the lack of surface water flow in the river; consequently the increased levels of SAR in the CBNG well production water directly relates to the reduction in the suitability of the water for irrigation purposes. In general, this trend is amplified for all streams during periods when CBNG well production water represents the majority of the flows available for irrigation purposes.