9.0 INTEGRATED AQUATIC ECOSYSTEM IFN

9.1 Background

As outlined in Section 4, there is a growing body of evidence to indicate that if protection of the aquatic ecosystem is the management goal for a river system, there must be a consideration of the interdependence between ecosystem components and processes, rather than the traditional narrow focus on fish habitat or water quality criteria. The case has been made that a single minimum flow determination does not result in the long term maintenance of the resource the recommendation was intended to protect (Stalnaker 1990, Annear et al. 2002). In those situations where a simple minimum instream flow objective has already been prescribed, based on only fish habitat or water quality criteria, a review of the IFN to incorporate the most recent scientific advances would be prudent. This was an essential task for the Technical Team for the SSRB WMP, where many reaches have instream flow objectives based on historical approaches.

9.2 IFN Integration Method

In spite of the wide recognition by IFN practitioners of the need to consider all elements of the aquatic ecosystem in defining an IFN, there is no universally accepted method for combining the different ecosystem components to develop an integrated flow recommendation.

The method developed by the SSRB Technical Team for integrating the different ecosystem IFN results is a straightforward process that generates results in a flow duration curve format, using a weekly time step compatible with the WRMM format. Inclusion of the IFN determination in the WRMM will only show whether or not various water management scenarios support meeting IFN targets. Operational details have not been considered at this point in the analysis, and are beyond the scope of the current report.

In general, water quality IFN determinations are provided as a single value for each week of the year for each reach where data were available. They are typically in the low flow range. Water quality values are often available for both winter and the open water seasons. The fish habitat IFN determination is a variable flow curve applied seasonally for each week in the open water season, excluding the typical spring freshet period. It generally applies to the moderate and low flow range. The riparian IFN determination is also a variable flow curve and is applied only during the growing season in the spring and summer, including the highest flow range. There was typically some overlap among the components, although one component often became the primary driver of the ecosystem IFN on a seasonal basis. The channel maintenance IFN determination was provided as a threshold flow, with a specified duration and frequency of occurrence. The channel maintenance IFN was not readily incorporated into a weekly duration format. Instead, a comparative analysis was conducted to ensure the IFN determination, using the riparian vegetation curve at the higher discharges, provided adequate flows for channel maintenance.

Both the fish habitat and riparian IFN determinations identified a base flow, below which no further reduction in flow is recommended. These are the uncommon low flow events that naturally stress a population and may limit overall population size. In situations when the natural flow is below these base flow determinations, the final integrated ecosystem IFN will be the same as the natural flow and no flow reductions are recommended. In most cases, the integrated IFN flows are always below or equal to the natural flow. The exception to this rule are flows that are required to meet the water quality IFN determination, based on the current loadings in the system (e.g. see Figures 9.1 and 9.2). Although the cases when water quality IFN exceeds the natural flow are typically limited to the winter weeks, it can also occur in the summer during dry years.

The IFN data for fish habitat, riparian vegetation, water quality, and the winter Tessmann values were entered into a spreadsheet for analysis. The recommended IFN value for each ecosystem component was compared, on a week by week basis, for every data point in the period of record. The component with the highest flow recommendation was selected as the flow value for the integrated IFN. The integrated flows were then sorted into weekly flow duration curves. In the simplest case, when all ecosystem components had IFN numbers available, the ecosystem component with the highest flow requirement defines the integrated IFN at that point (Figure 9.1).

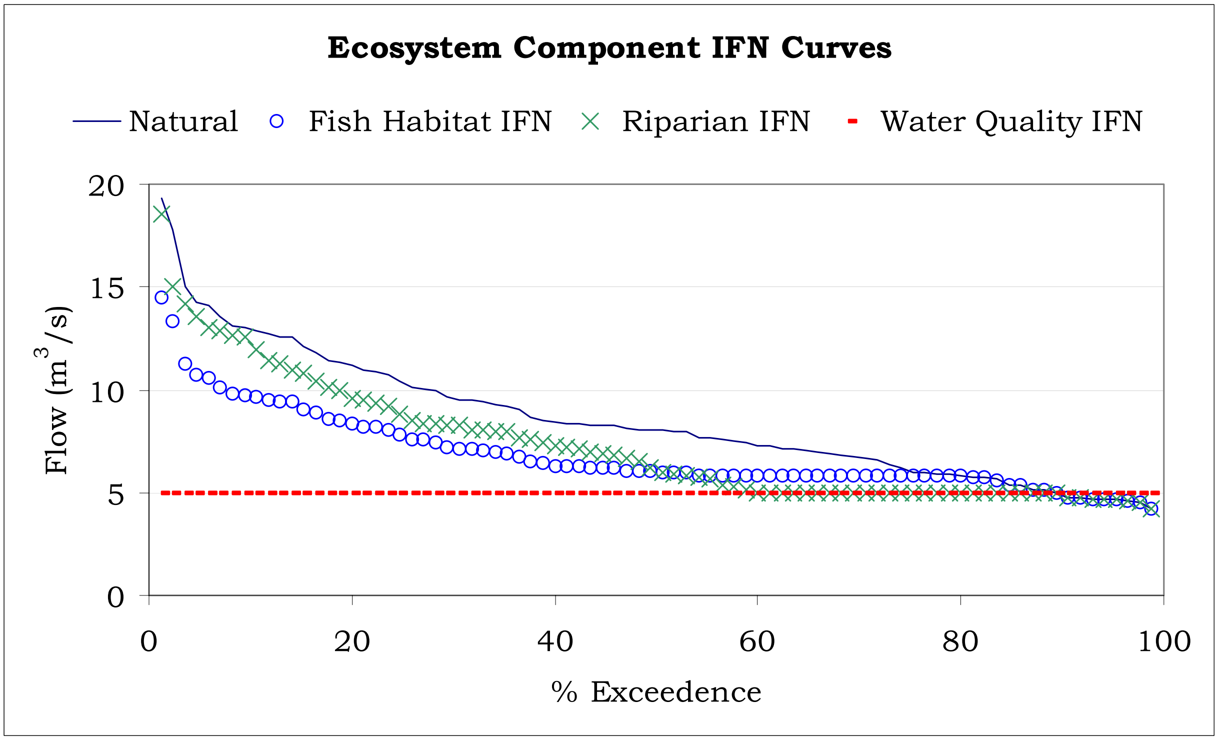
However, not every component has data available, or suitable, for the entire year or for every reach under review. As an example, the riparian IFN determination was only applied during the period when the riparian poplars are not dormant. Therefore the integrated IFN only has a riparian component incorporated during weeks 15-37 (early April to mid-September). The fish habitat derived IFN values were not applied during the spring freshet period (typically mid-May through mid-July) for every reach under review. Therefore, the integrated IFN during the spring is often defined entirely by the riparian IFN determination, regardless of the flow. This reflects the seasonality of the hydrograph and the corresponding biological functions that have adapted to the timing of high flows, such as riparian poplar recruitment.

Although a fish habitat IFN determination is not made during the spring freshet using fish habitat information, these flows are still necessary for fish and other aquatic biota. They form and maintain the habitats and energy pathways that define the aquatic ecosystem. Fish habitat data were also not available for the winter weeks, and the integrated IFN is comprised entirely of either the water quality IFN determination or an office based method for fish habitat (the Tessmann calculation).

An annual hydrograph showing the typical chronology of each of the ecosystem components and the resulting integrated ecosystem IFN is presented in Figure 9.2. Of particular note in Figure 9.2 are the seasonal distribution of the ecosystem component IFN determinations and the flow magnitude distribution shown in Figure 9.1. In this example for the Oldman River near Monarch (reach OM4), there is no fish habitat IFN determination for weeks 17-28 inclusive.

Figure 9.1 provides an example of how the integration process follows the basic criteria for selecting component values, to build the integrated IFN related to both timing and flow magnitude. However, this general pattern of integration does not occur in all cases. As an example, the water quality IFN can often be below both the fish habitat and riparian IFN for most of the year, and not form part of the integrated IFN curve. Another common pattern was that the fish habitat and riparian curves were very similar in some flow ranges, and the two curves occasionally crossed back and forth. As a result, a clean transition between ecosystem components as illustrated in Figure 9.1 does not always occur.

Another consequence of the integration process is that similar IFN flows can be prescribed by any of the three components, depending on the time of year (Figure 9.3). The reason for this pattern is two-fold: first, not all components provide an IFN determination for every week of the year; and secondly, the hydrograph is seasonal. The second reason refers to the fact that a flow of a given magnitude may be greater than normal at one time of the year, but that very same flow value may be much below normal at a different time of year.



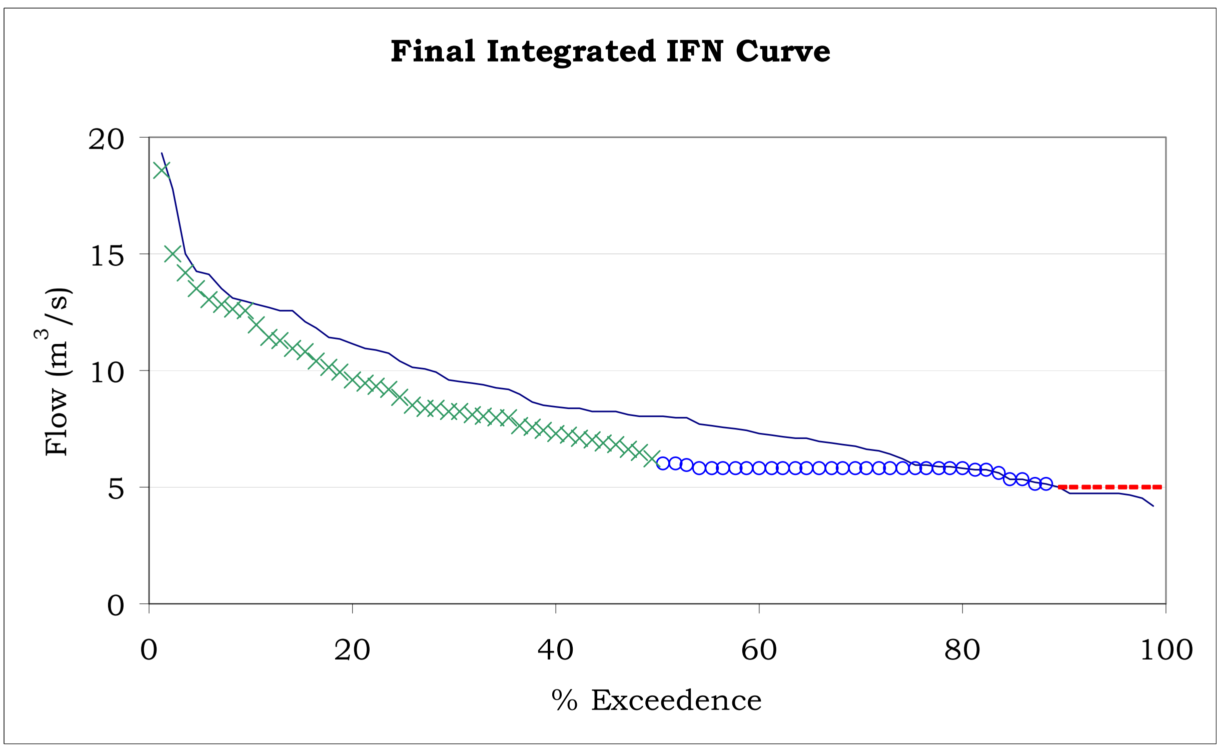
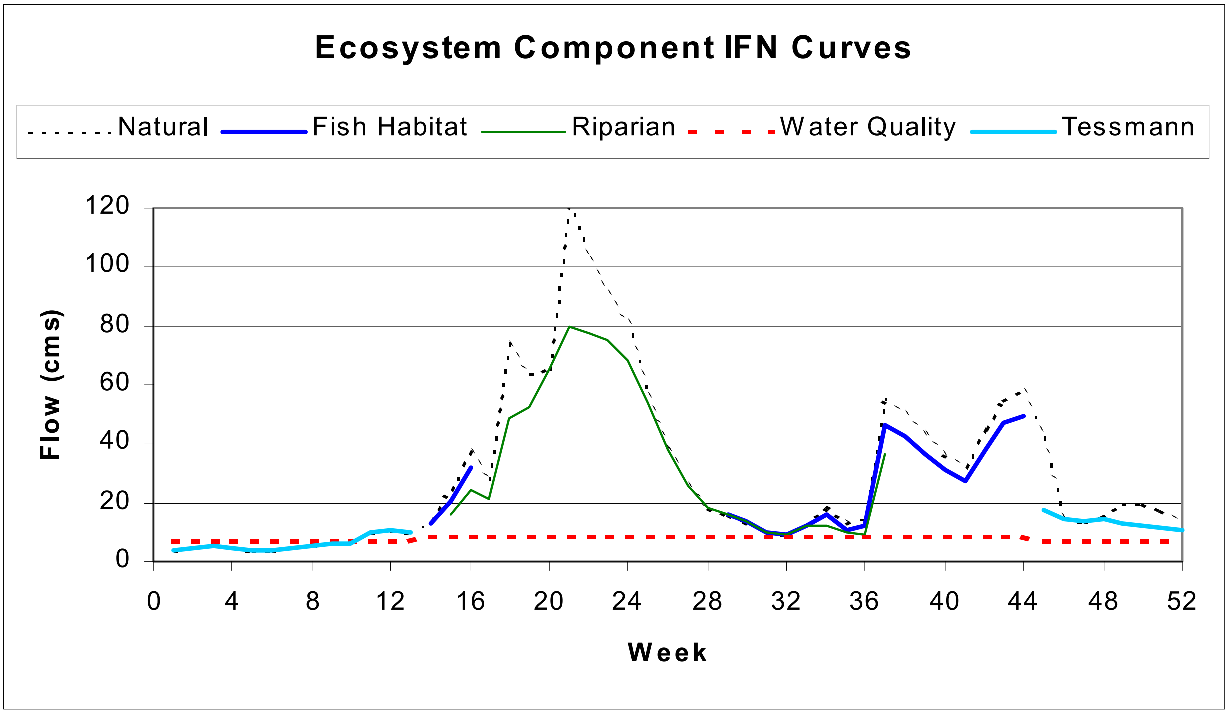


Figure 9.1. Illustration of how each ecosystem component was integrated into the final ecosystem IFN curve for Week 33 on the Belly River near Standoff (reach BL2).



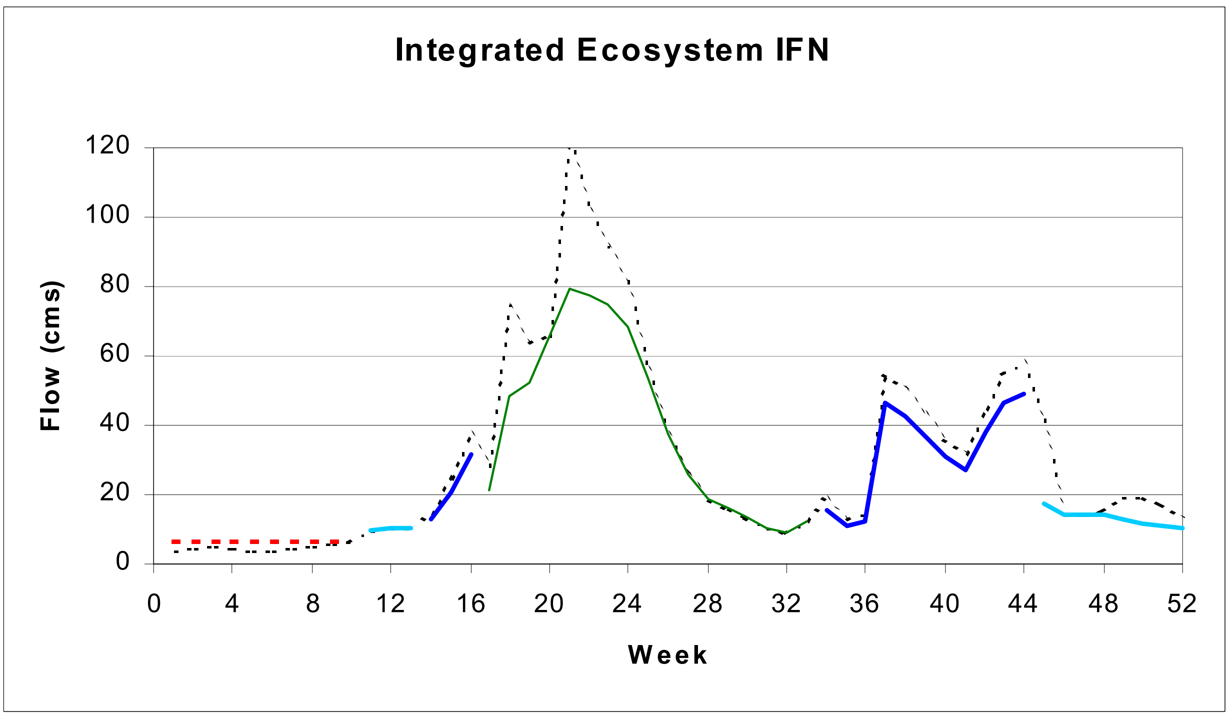


Figure 9.2. Illustration of the seasonality of each ecosystem component (top graph) for 1985, a drier than average water year (based on the mean annual flow) and the resulting integrated ecosystem IFN (bottom graph). The Oldman River near Monarch (OM4).

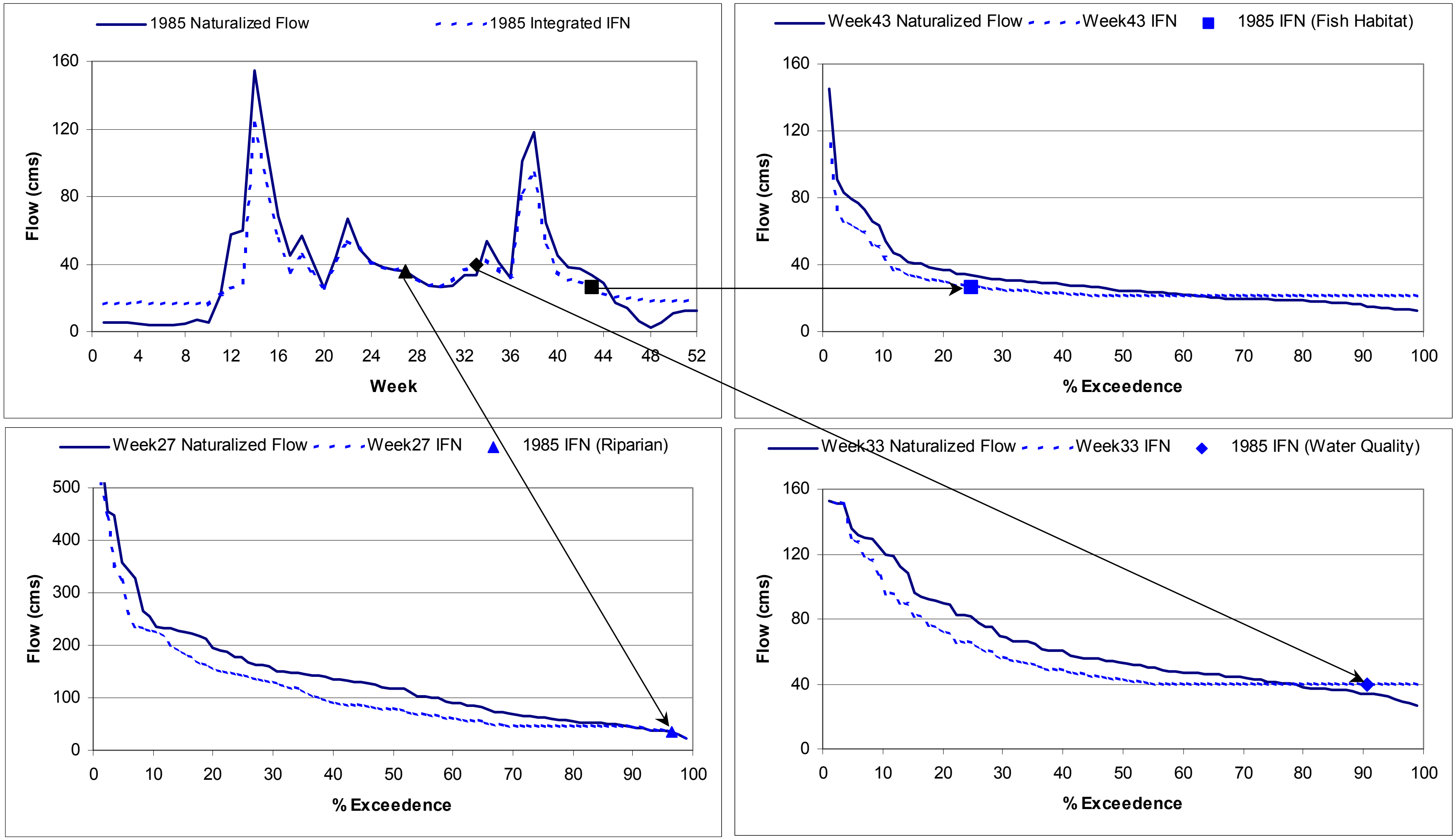


Figure 9.3. An illustration of the seasonality of the naturalized hydrograph and the resulting integrated ecosystem IFN for the Red Deer River (reach RD3) using 1985, a drier than average year. The weekly duration curves indicate the individual ecosystem component that determined the IFN for that week in 1985.

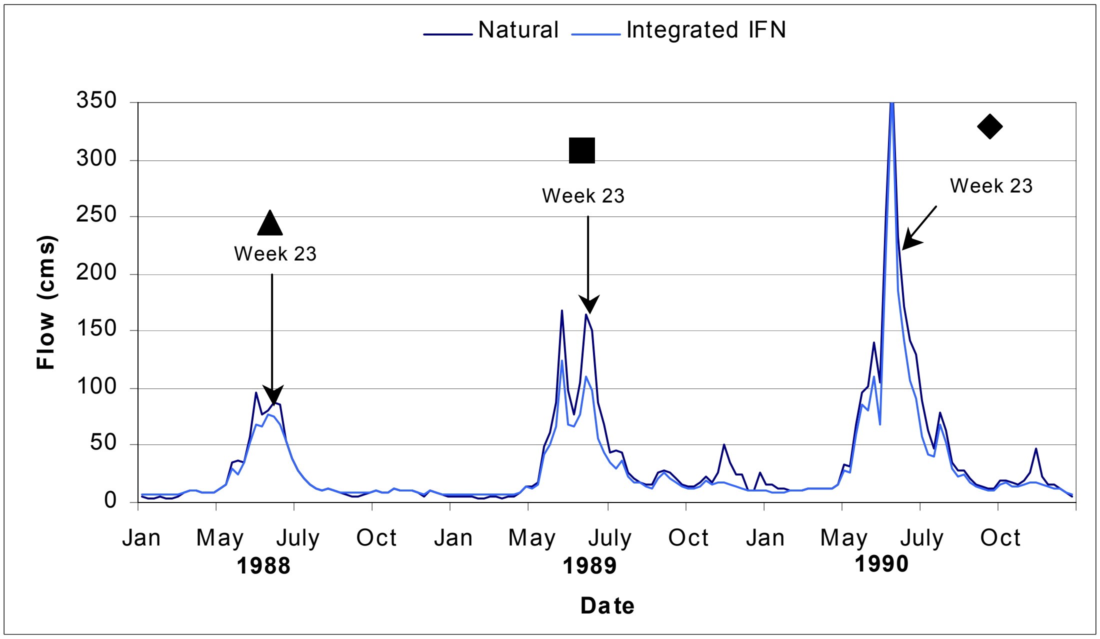
As discussed in previous sections, the seasonal timing of flow magnitude can be very important biologically. A relatively high flow occurring in the late fall may not be as important to some biological processes as it would be if that same flow had occurred during the spring freshet, when many biological functions are directly linked with high flow events. Therefore, the IFN determination would be expected to indicate that little water should be removed from the river in the spring to protect riparian processes, but that a greater reduction would be acceptable in the late fall, depending on the site-specific fish habitat and water quality requirements.

Figure 9.3 provides an example of this situation on the Red Deer River at Drumheller (Reach RD3) for 1985, a drier than normal year. In week 27 at the beginning of July, a flow of 35.9 m^3/s is an uncommonly low flow (~96% flow exceedence). The resulting IFN determination is therefore the same as the naturalized flow at 35.9 m^3/s, based on riparian IFN requirements. For week 33 in mid-August, the flow is once again uncommonly low at 33.6 m^3/s (~91% flow exceedence). However, at this time in the summer, water quality becomes a greater concern and the resulting IFN is increased over the naturalized flow to 39.9 m^3/s to meet IFN requirements for water quality. In week 43 at the end of October, when the flows in the Red Deer River are normally low, the naturalized flow at 33.4 m^3/s is higher than average for that time of year (~25% flow exceedence). The resulting IFN determination allows for a reduction to 26.7 m^3/s based on the fish habitat IFN results.

Although the naturalized flows in Figure 9.3 for the three weeks indicated are very similar (35.9, 33.6, and 33.4 m^3/s), the resulting IFN determination and the ecosystem component that defines the integrated IFN for each week are quite different. This is due to the seasonality of the natural hydrograph and the seasonality of each ecosystem component. In the other weeks of the year it can be seen in Figure 9.3 that the IFN varies, depending on both the natural flow and the time of year. The rationale for this is provided in Section 4 and is also discussed throughout the report. In essence, the reason the IFN varies within each year is to protect the intra-annual flow variability to which the riverine ecosystem is well adapted. The other component of flow variability that the Technical Team identified as critical for the protection of the aquatic ecosystem is the inter-annual, or between years, flow variability. As witnessed in Alberta in the last decade, there were years of very high flows, such as 1995 in the Oldman River sub-basin, and drier years, such as 2002 was for many locations across the province. The ecosystem IFN is designed to protect both this inter-annual flow variability and the intra-annual seasonality of flows.

To help explain this step, Figure 9.4 illustrates three consecutive flow years for the Oldman River near Monarch (OM4). From 1988 through 1990, the Oldman River experienced a very dry year (1988), a slightly drier than average year (1989), and a wetter than average year (1990), based on the mean annual flow. If a single week of the year is taken, such as the first week in June (week 23), and all available flows for every year that data are available are sorted from highest to lowest, a flow duration curve is generated (Figure 9.4). The flows from the three years indicated above can be identified as points on the duration curve. The exceedence values for week 23 in 1988, 1989 and 1990 were 86%, 49%, and 27% respectively. Using the IFN exceedence curve for week 23, a different IFN flow is prescribed for that week in each of the three years (Figure 9.4). These different flows protect long term inter-annual flow variability.

The exact component and the time of year that each component contributes to the IFN should not be of concern because the end goal of the Technical Team is to provide a singular ecosystem IFN curve that should be viewed as protecting the entire ecosystem on a seasonal and inter-annual basis. The Technical Team produced an IFN evaluation for each component separately, but always with the intent that the individual results would be used to form an integrated ecosystem IFN determination that would protect the complex physical and biological interactions of a natural aquatic ecosystem.



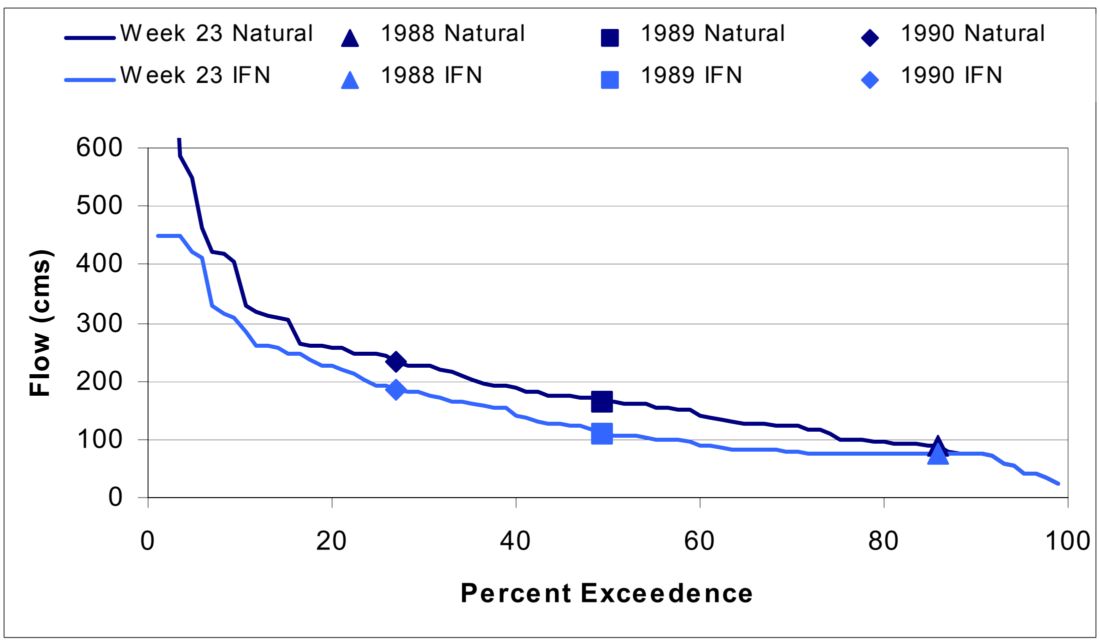


Figure 9.4. An illustration of inter-annual flow variability (top graph) for a dry (1988), average (1989) and wet (1990) flow year for the Oldman River near Monarch (reach OM4) and the associated flow duration curves (bottom graph) for week 23 illustrating the variable ecosystem IFN determination.

9.3 Integrated Ecosystem IFN Determinations

Using the approach described above, an integrated ecosystem IFN determination was derived for each week, for each of the 27 reaches being evaluated as part of the SSRB WMP (see Tables 3.1-3.5 for reach descriptions). Due to the site-specific hydraulics, channel form, species composition or locations of nutrient loadings, the IFN will vary both from week to week and from reach to reach. An ideal pattern would result if the IFN followed a pattern similar to the hydrology from upstream to downstream, that is, IFN prescriptions would increase progressively with distance downstream. This is not always the case. In some instances, the IFN can decrease from one reach to the next downstream reach, and then increase again for the following downstream reach. The IFN determinations were not 'balanced' from upstream to downstream to adjust or account for these differences. However, this is a necessary step before proceeding into the next phase of water management planning for both the main stems and the tributaries.

A representative reach was selected for each of the main rivers assessed, to illustrate the integrated IFN results within each sub-basin. The selection of representative reaches was done, in part, by using the overall availability of the site-specific data for each reach. A map indicating overall data availability is provided in Figure 9.5. The evaluation of available input data required to make a site-specific IFN determination was made for each component using four categories: no site-specific data or modelling (score = 0), limited site-specific data or modelling (score = 1), acceptable site-specific data or modelling (score = 2), and good site-specific data or modelling (score = 3). The rating provided in Figure 9.5 is based on the sum of the individual component evaluations, and the category scores are then defined as 0-3, 4-6, 7-9, and 10-12 for no data, limited data, acceptable data, and good data respectively.

The availability of input data for each component is evaluated slightly differently. The water quality evaluation is based primarily on available modelling information that is used for IFN evaluations, rather than on the availability of water quality data. Most reaches have sufficient water quality data, but for some reaches, such as for the lower Bow River and the South Saskatchewan River, the modelling required to develop the water quality IFN has not been done. For fish habitat, the evaluation is based on the availability of PHABSIM modelling data. For reaches with no PHABSIM data, the provincial standard office-method (Tessmann) was applied. Within the riparian IFN process, the lack of site-specific IFN data indicates an inability to verify flow determinations. However, the robustness of the riparian model on other reaches suggests that although additional validation work is needed before refining IFN estimates, the determination provided is adequate for a planning level study. For reaches with no channel maintenance data, the 5 year return flow was used as the surrogate against which integrated IFN determinations were compared.

Although it is indicated in Figure 9.5 that no data or limited data are available for determining IFNs for some reaches, it should not be concluded that the IFN provided is not valid. In situations where site-specific data or modelling are not available, an acceptable surrogate has been found that is adequate to define the flows required for ecosystem protection in a planning level study.

A sample reach for each sub-basin is provided in Figures 9.6 through 9.12. The natural flow exceedence curve and the integrated ecosystem IFN determinations are shown for weeks 9, 23, 33, and 40 of each sample reach, to illustrate seasonal variability. Week 9 at the beginning of March is included to represent the winter low flow period. Week 23 at the start of June is used to represent the freshet weeks, typical of the spring and early summer. Week 33 in mid-August is used to represent the late summer conditions. Week 40 at the beginning of October is used

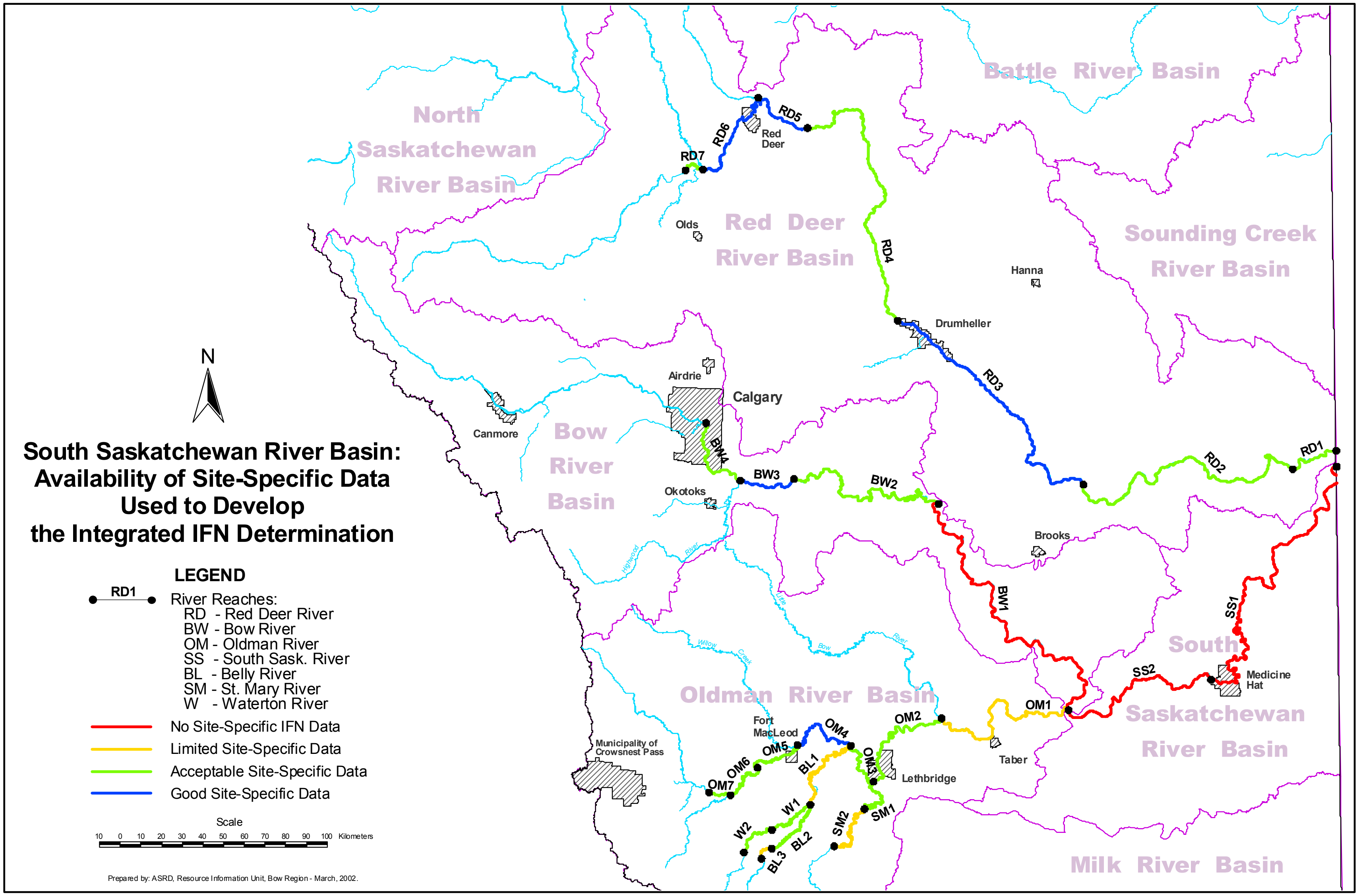


Figure 9.5. Summary of the combined reach-specific input data availability required for a detailed IFN determination to develop the integrated ecosystem IFN throughout the SSRB.

to represent the fall season. The natural flow and the integrated IFN are presented in flow duration format to help illustrate the inter-annual flow variability for each reach at different times of the year. The reaches chosen as examples are provided to show the general pattern within each sub-basin. The ecosystem IFN is similar for each sub-basin, in that the IFN curve provides a variable flow that follows the general pattern of the natural flow variability. However, there are some differences among the sub-basins as well.

The Red Deer sub-basin is characterized as having an IFN that exceeds the natural flow for much of the winter and, to a lesser extent, in the summer weeks of dry years (Figure 9.6). This is due to the water quality IFN necessary to meet the current loadings into the Red Deer River. The Bow River also has water quality IFN values above the natural flow in the winter. However, this rarely occurs for the remainder of the year (Figure 9.7). The Oldman River and the Southern Tributaries IFN rarely exceed the natural flow in order to meet water quality requirements (Figures 9.8 - 9.11). The South Saskatchewan River IFN is characterized by a lack of fish habitat data, resulting in a flat-line IFN at certain times of the year (Figure 9.12). This indicates limited inter-annual flow variability that needs to be addressed in future work.

The data for every week and every reach are available in Appendix G.

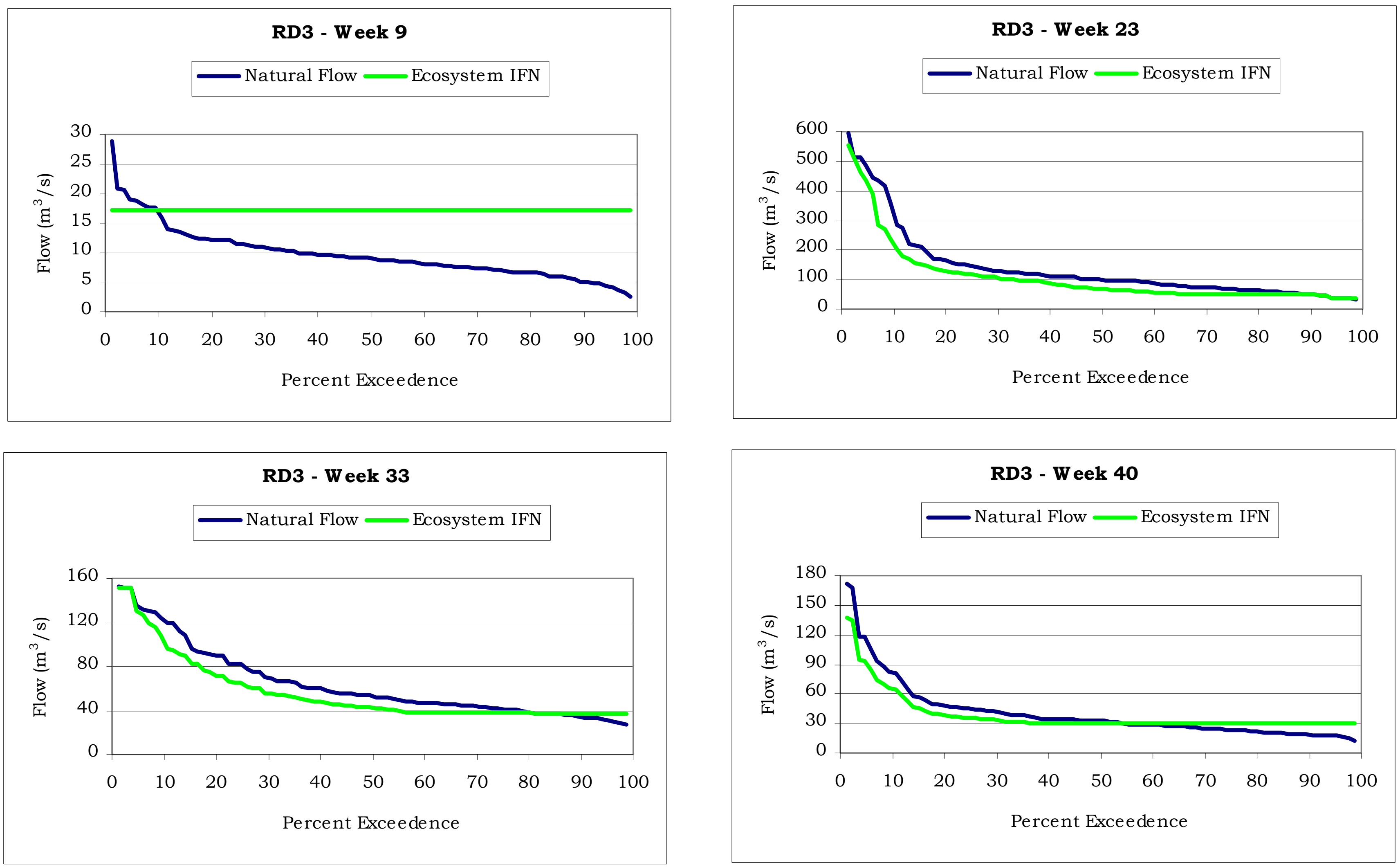


Figure 9.6. The Red Deer River at Drumheller (RD3) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

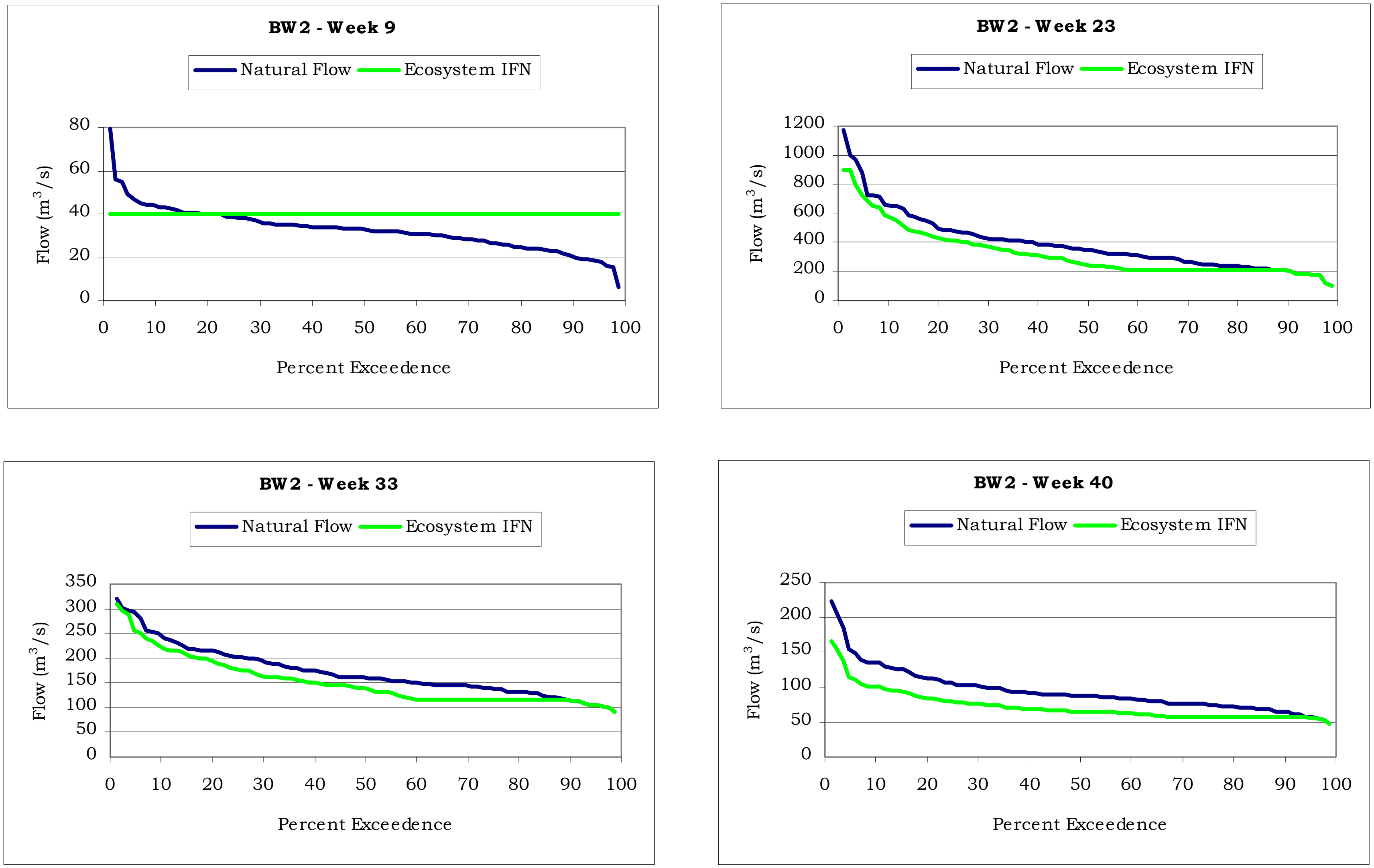


Figure 9.7. The Bow River below the Carseland weir (BW2) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

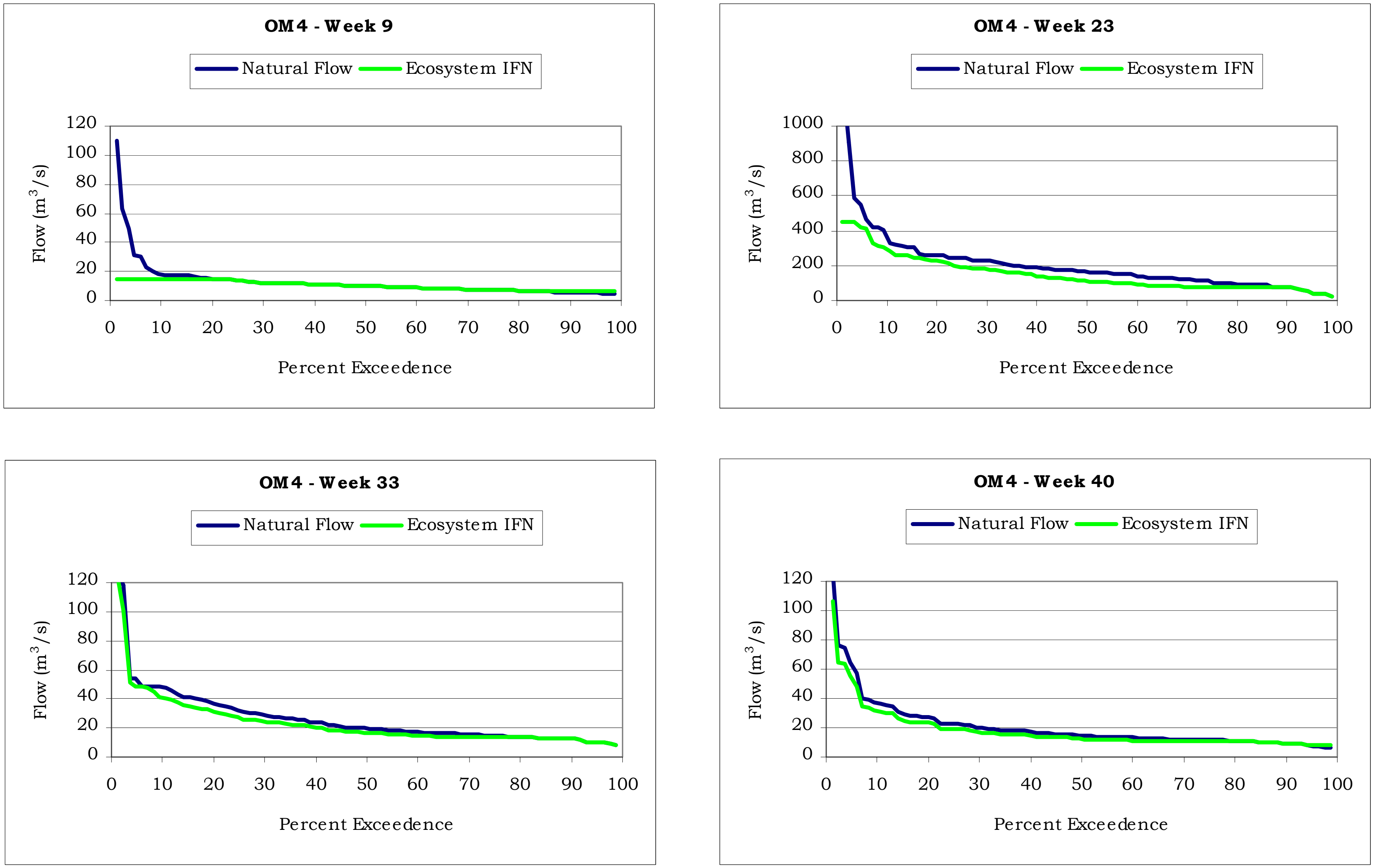


Figure 9.8. The Oldman River at Lethbridge (OM4) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

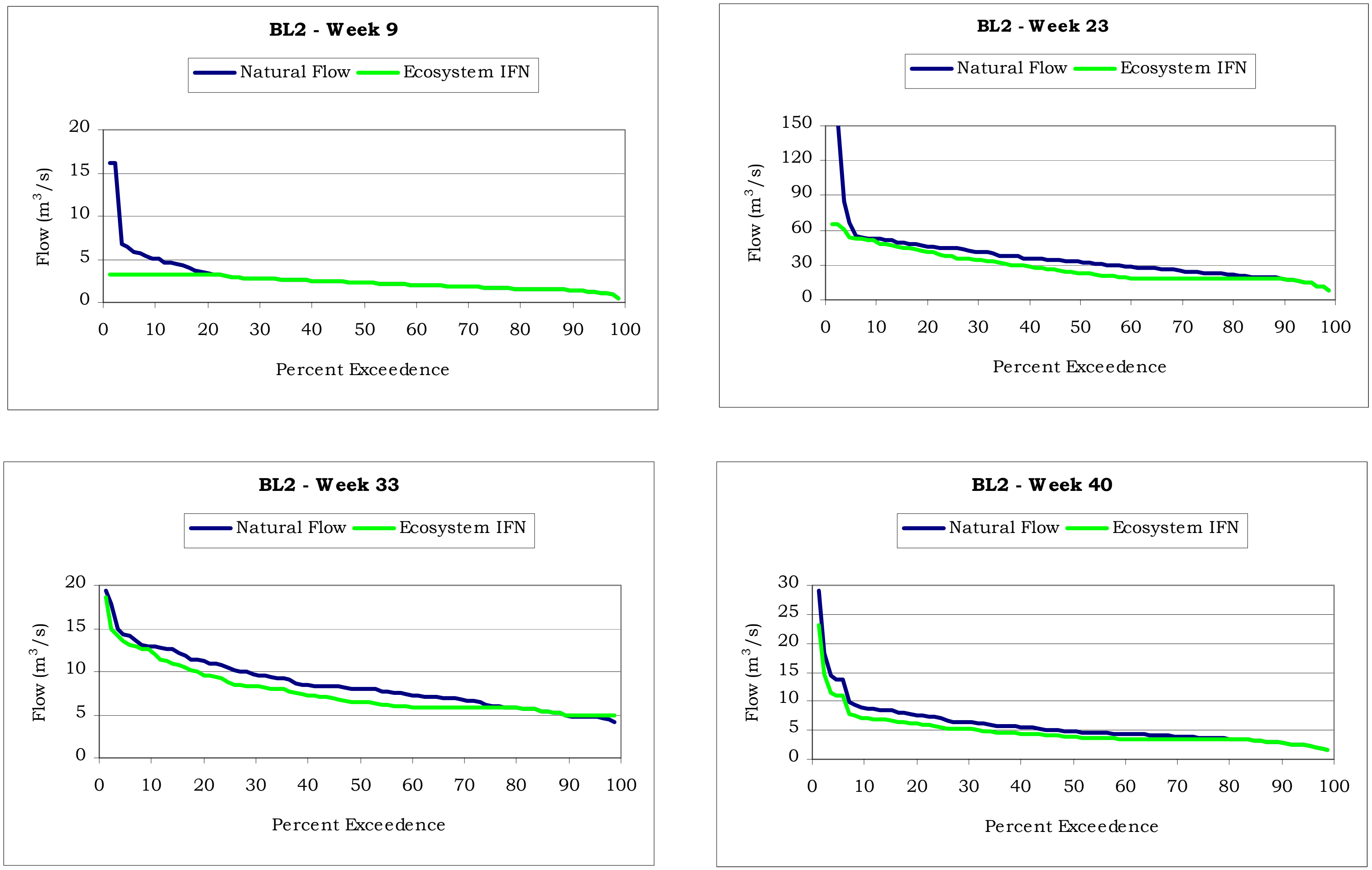


Figure 9.9. The Belly River near Standoff (BL2) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

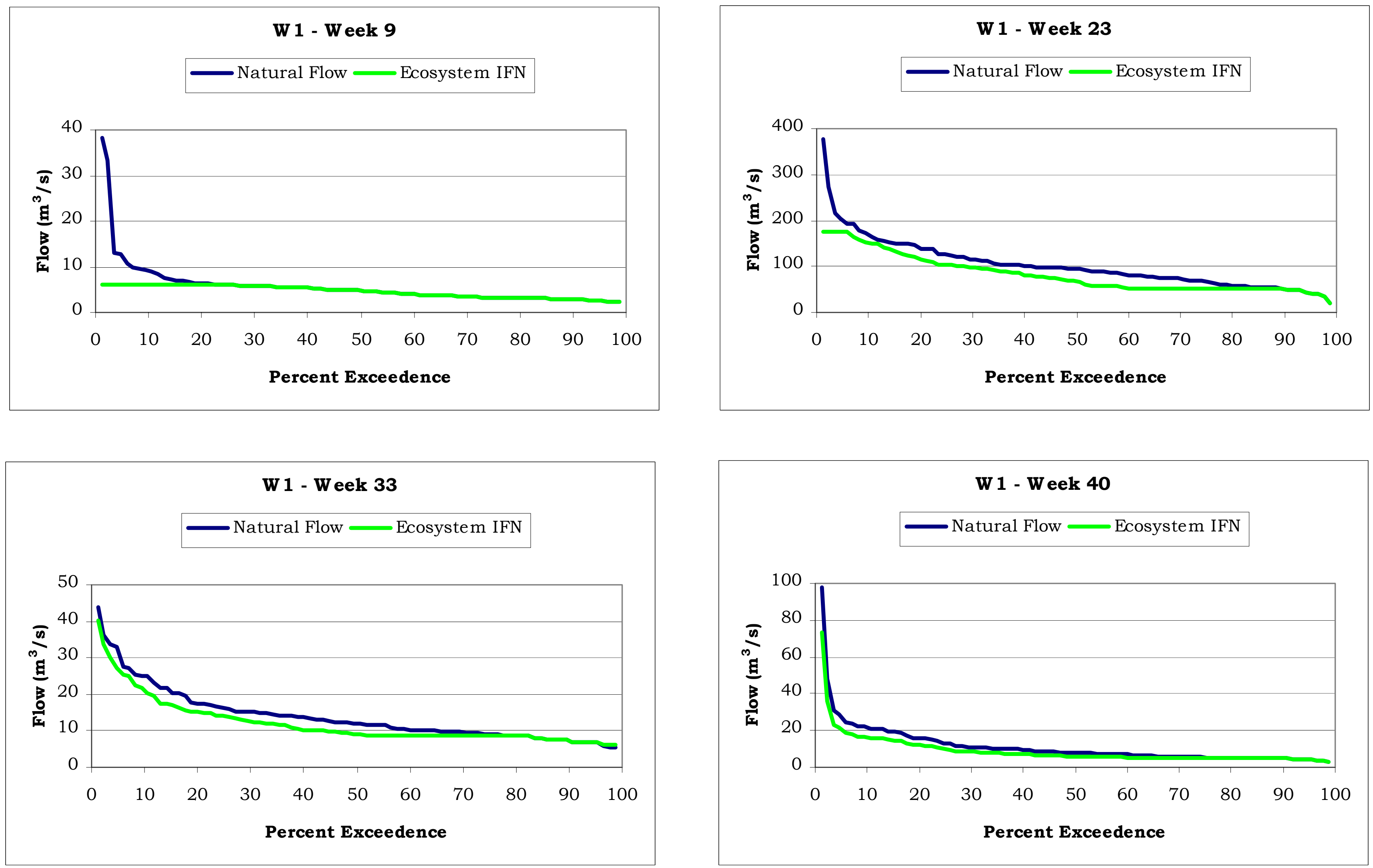


Figure 9.10. The Waterton River near Standoff (W1) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

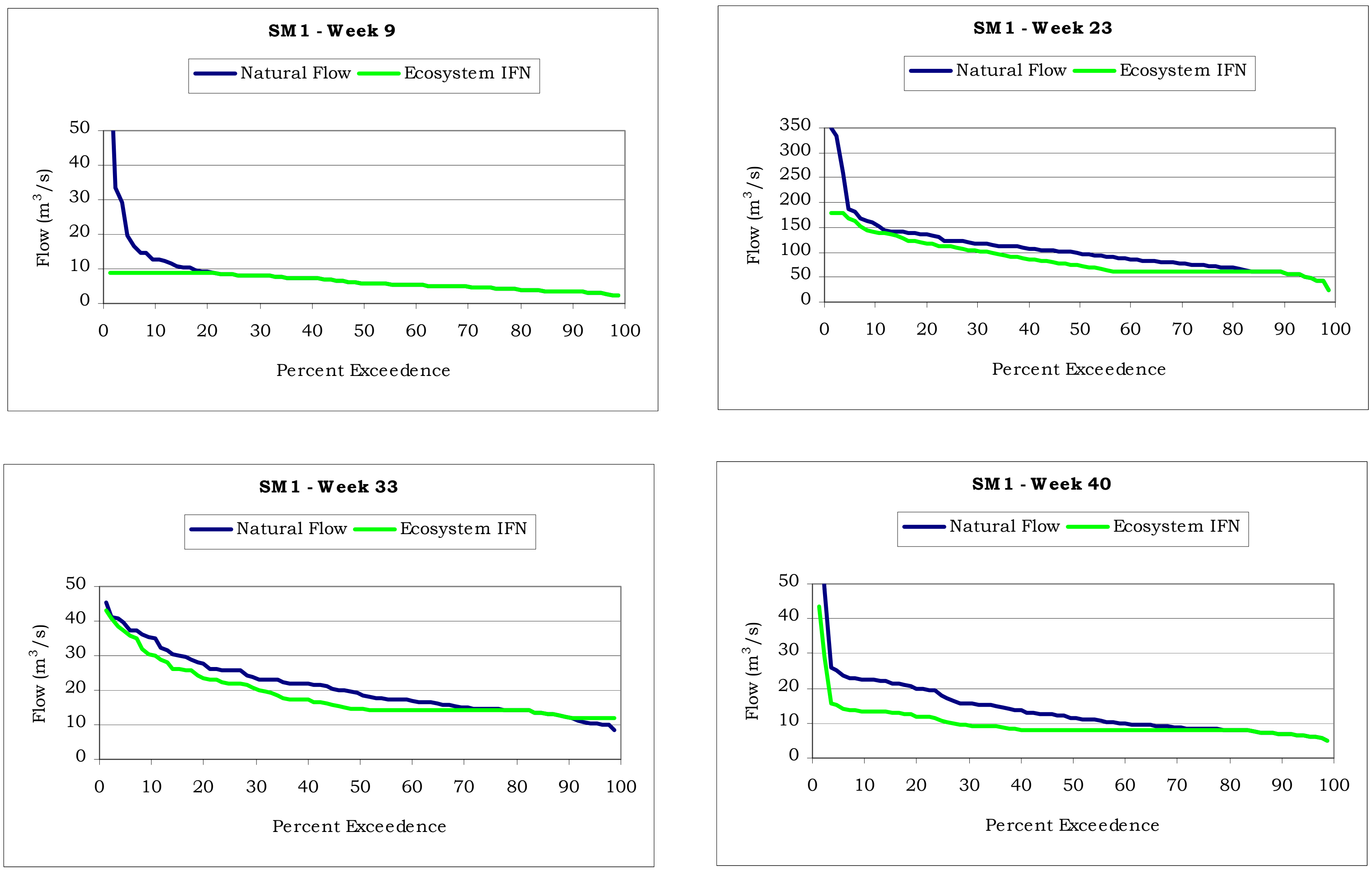


Figure 9.11. The St. Mary River near Lethbridge (SM1) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.

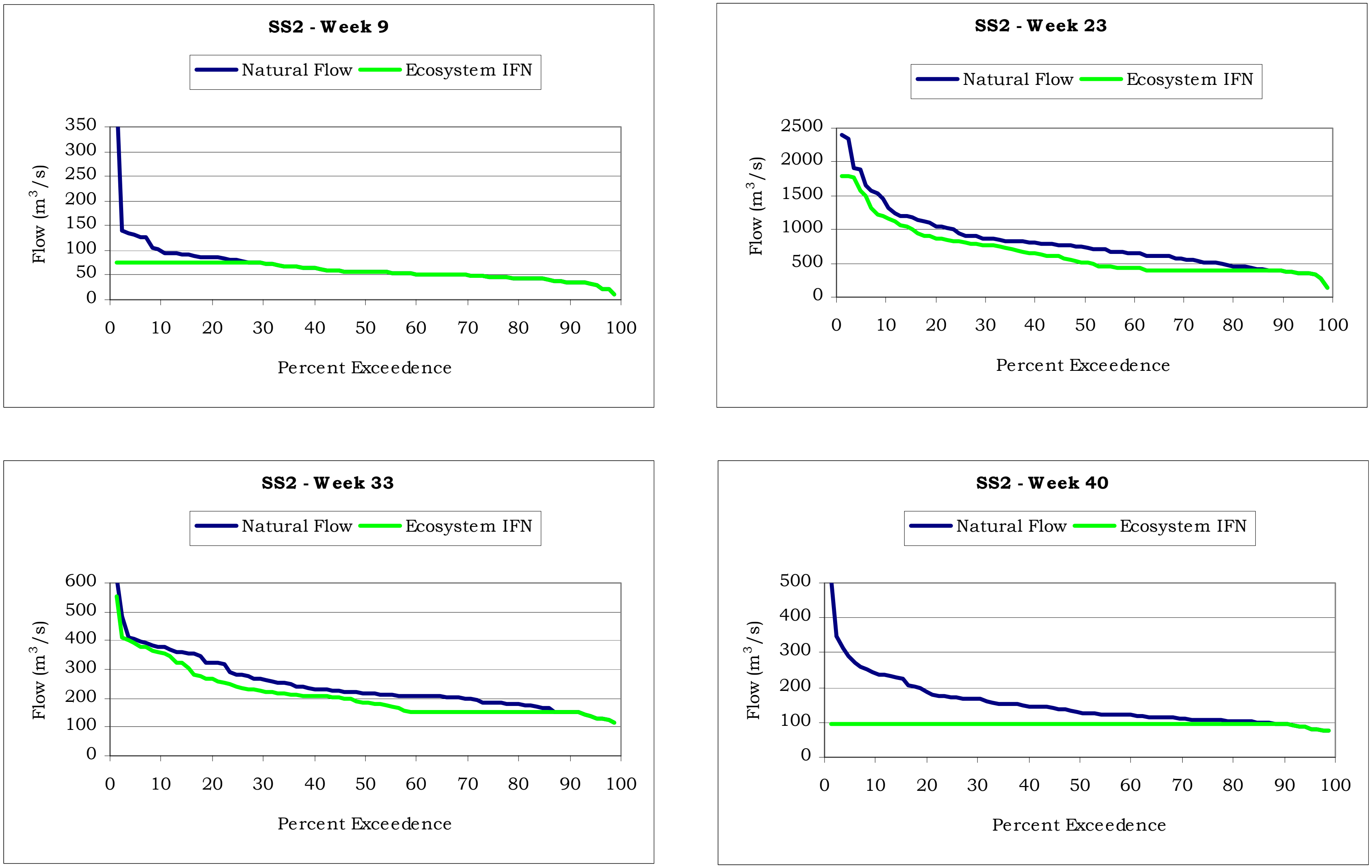


Figure 9.12. The South Saskatchewan River at Medicine Hat (SS2) integrated ecosystem IFN for weeks 9, 23, 33, and 40.

Note: the scale on the vertical axis (flow) changes between weeks.