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SOURCES OF SALINITY TO THE MUSSELSHELL RIVER: EXECUTIVE SUMMARY

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The Musselshell River is the primary source of irrigation water in Musselshell County, Montana. However, high levels of salinity occasionally make the river an unsuitable source of irrigation water. Salinities that approach or exceed the irrigators' threshold of 3,000 µS/cm occur in some years during early spring and late fall. High-salinity irrigation water can damage soil and crops. At the request of the Musselshell Watershed Coalition, the Montana Bureau of Mines and Geology Ground Water Investigation Program investigated the groundwater/surface-water system along the Musselshell River in eastern Musselshell County (fig. 1) to identify if improvements to irrigation infrastructure would reduce river salinity.

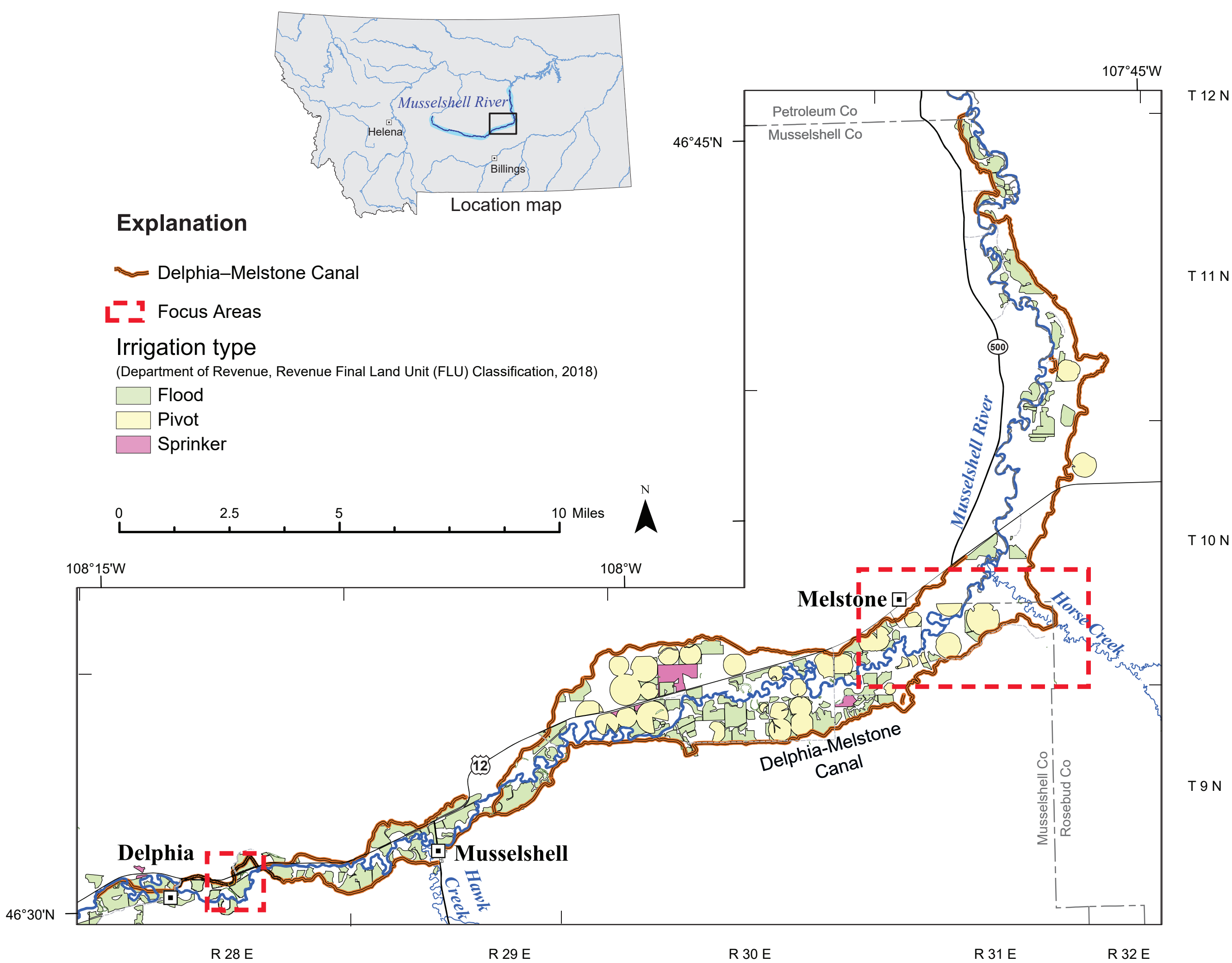

Figure 1. The study area included the groundwater and surface water along the Musselshell River in Musselshell County from Roundup to Petroleum County. Two focus areas were chosen to capture the geologic variability: sandstones by Delphia and shale by Melstone.

Effect of Irrigation on Groundwater

Leakage from irrigation canals and the application of irrigation water can raise the water table (fig. 2). This higher water table can dissolve available salts from the soil and applied agricultural amendments. Dissolved salts can migrate to groundwater, to the soil surface, or to surface water. Efforts to reduce salt contributions to surface water can include lining canals or installing efficient irrigation systems, such as sprinklers and pivots. These two solutions were evaluated for effectiveness if implemented along the Musselshell River.

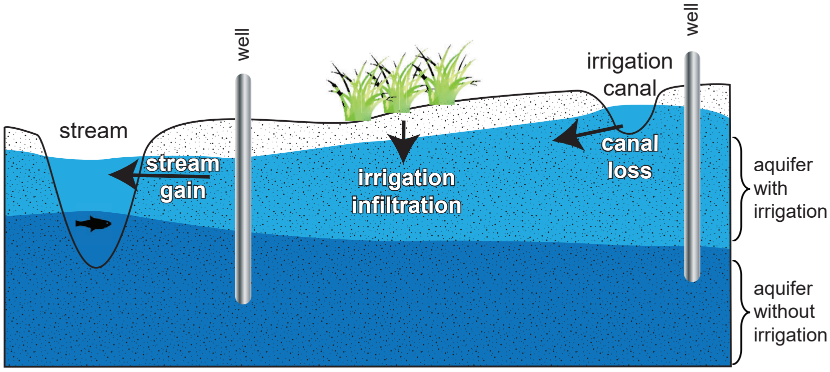

Figure 2. Applied irrigation water and leaking canals raise the water table, which dissolves naturally occurring salt in the soil.

Irrigation Return Flows Contribution to River Salinity

Elevated river salinity in the spring and late fall/winter occurs when high-salinity groundwater discharge to the river represents a larger fraction of river flow; this condition is associated with lower overall river flow rates (fig. 3). High river salinities in the spring are not irrigation related; however, irrigation practices that recharge groundwater can increase the amount of groundwater discharged to the river during the summer and fall.

In late summer and early fall of 2020, irrigation return flows increased the salinity of the Musselshell River from Delphia (~1,300 µS/cm) to Melstone (~1,600 µS/cm) by approximately 20 to 30 percent (July–Sept., 2020; fig. 3). However, the contribution of irrigation-related groundwater to the river's salinity does not negatively impact irrigators because it is diluted by releases of low-salinity water from upstream reservoirs during the irrigation season.

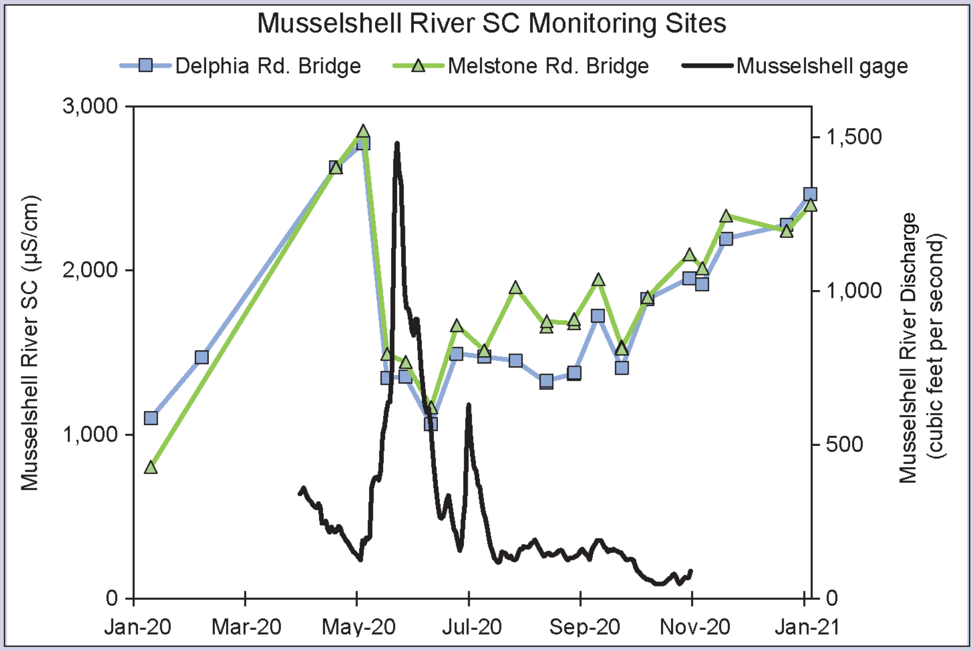

Figure 3. Specific conductance (SC) is a measure of the salty-ness (salinity) of the water. The highest river salinity occurs when the river flow rate is lowest because groundwater represents a larger portion of the overall flow. From Delphia to Melstone, irrigation water returning to the river through the groundwater increases the river salinity during the summer and late fall.

Canal Leakage Contribution to Groundwater

Sixteen monitoring wells, on four irrigated fields and two unirrigated fields, were installed near Melstone and Delphia to monitor the interaction of canal leakage, groundwater, and the Musselshell River. Wells were instrumented to measure groundwater level and salinity through 2020 and 2021. Monitoring results showed canal leakage was a source of recharge to shallow groundwater at all four monitored sites (fig. 4).

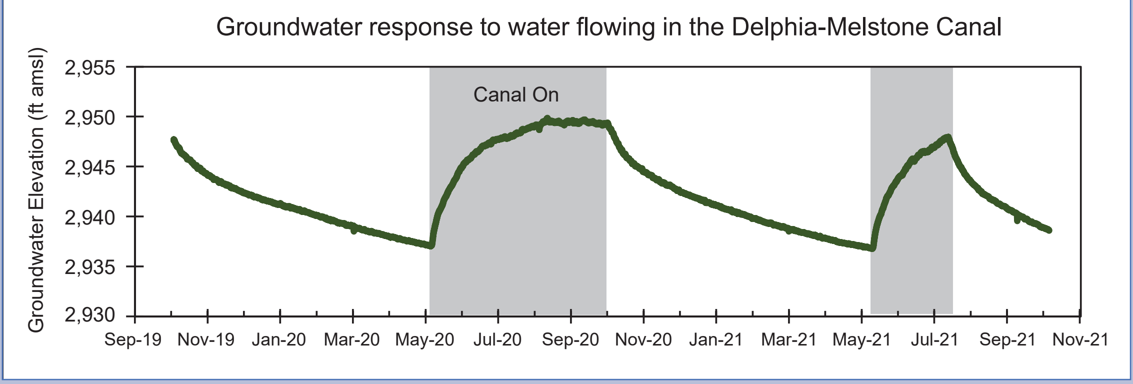

Figure 4. Groundwater levels rise within 48 hours from when the Delphia–Melstone Canal begins carrying water. Drought conditions in 2021 resulted in a foreshortened irrigation season.

Contribution of Applied Irrigation Water to Groundwater

Soil cores were collected from flood- and pivot-irrigated fields, as well as fields that had never been irrigated (fig. 5). Soil moisture probes were also installed on these fields to measure soil moisture at 2, 5, and 10 feet below ground.

Soil core profiles and soil moisture measurements indicate that, while the flood irrigation recharged groundwater, the pivot irrigation did not. The infiltrating irrigation water dissolved the naturally occurring salts in the soil. On the flood-irrigated site, these salts entered the groundwater. On the pivot-irrigated site, they have accumulated below the rooting zone. However, salt mobilized through pivot-applied irrigation may reach the Musselshell River through surface runoff rather than through a groundwater pathway.

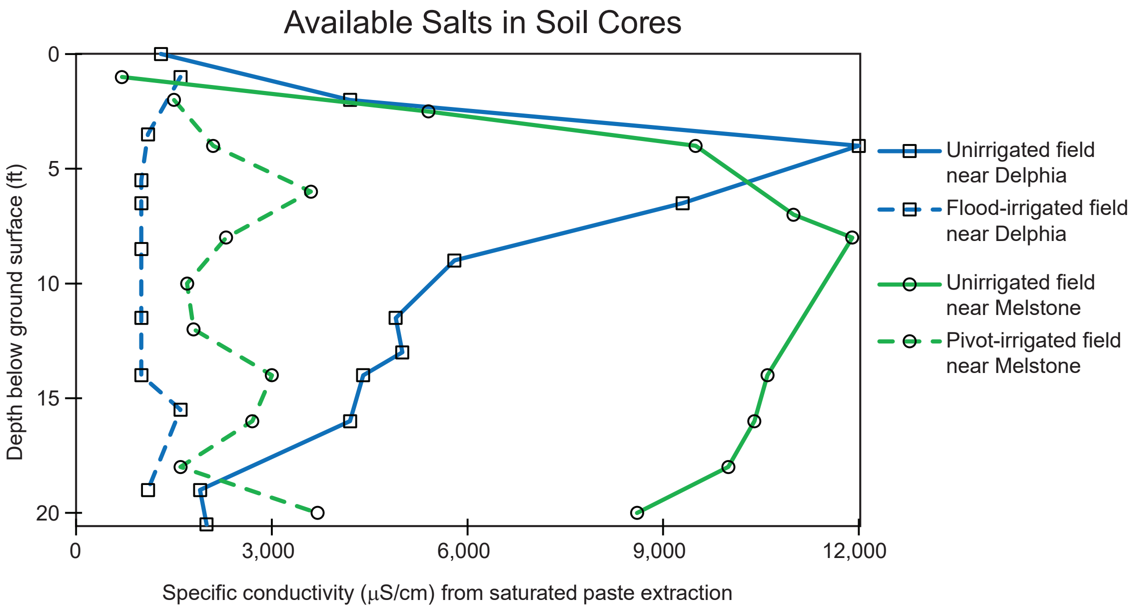

Figure 5. The unirrigated field near Delphia has a lot of salt available near the surface, while the unirrigated field near Melstone has a lot of salt available throughout the profile. Salt has been uniformly flushed through the soil on the flood-irrigated field near Delphia, while salt accumulates below the rooting zone on the pivot-irrigated field near Melstone.

Conclusions

The high Musselshell River salinity in the spring is not irrigation related, but is a result of the seasonal dominance of groundwater entering the river and the naturally-occurring salts in the soil and rock dissolved into the groundwater.

In late summer and early fall, irrigation return flows increase the salinity of the Musselshell River from Delphia to Melstone by approximately 20 to 30 percent. However, this increase occurs when the river salinity is low due to upstream reservoir releases. Despite this increase, the salinity remained below the 3,000 µS/cm irrigation threshold.

The river chemistry is more dominated by sodium, magnesium, and sulfate during low flows, indicating the increasing influence of groundwater baseflow. Irrigation practices increase the amount of baseflow during late fall and winter, but the higher salinity does not occur at a time when the river is being used for irrigation.

Soil profiles record the history of irrigation-related salt dissolution. Unirrigated soils have high levels of available salts; however, soils in the Melstone study area have more salt available at depth compared to soils in the Delphia area. Irrigated soils have lower levels of salts throughout the soil column as compared to never-irrigated soils. However, the application of irrigation water still mobilizes salts on the monitored flood- and pivot-irrigated fields.

Recommendations

Marginal improvements to lower the salinity of the river could be achieved through the installation of center pivots (replacing flood irrigation) or lining the irrigation canals; however, these would not prevent the river from approaching 3,000 µS/cm in the early spring, when groundwater baseflow makes up a large portion of total flow in the river.

While canal lining preserves irrigation water for downgradient users, it may lead to unintended consequences. Leakage from the Delphia–Melstone Canal provides low-salinity recharge water to the shallow aquifers. The resulting higher water table can provide sub-irrigation to crops.

Canal lining and pivot installations, while unlikely to to improve river salinity in a consequential way, can advance other desired outcomes such as reducing muddy conditions below leaking canals, reducing erosion through managed irrigation, or conservation of irrigation water.

Releases from upstream reservoirs of low-salinity water are key to maintaining low river salinities in the summer months. As precipitation patterns become less predictable, additional storage capacity to retain more low-salinity spring run-off would provide irrigators with more stability during the irrigation season.

Acknowledgments

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ADDITIONAL RESOURCES

The full report can be found on the Montana Bureau of Mines and Geology Publications page:

Meredith and Kuzara, 2023, Sources of Salinity to the Musselshell River, Musselshell County, Montana. Montana Bureau of Mines and Geology Report of Investigations 35.

http://mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=32528&

Online access to all project data is available on the Ground Water Information Center database: https://mbmggwic.mtech.edu/, under Project Code: Ground Water Investigation Program > Billings.