



Positive Effects of Small Dams and Reservoirs



Water quality and quantity findings from a Prairie watershed

Summary: Small on-farm earthen dams can reduce downstream peak flow and associated flooding in agricultural watersheds, and can significantly reduce sediment, nitrogen (N) and phosphorus (P) loadings to streams. Researchers in the South Tobacco Creek Watershed in Manitoba have observed these sediment and nutrient reductions immediately downstream of the dams. Computer modelling is underway to predict whether these same values might be reflected further downstream—at the outlet of the watershed or beyond. If so, the cost of constructing and operating the dams could be offset by the public benefits they can bring in terms of controlling water quantity and improving water quality.

The 7,500-hectare (18,500-acre) South Tobacco Creek Watershed is located in south-central Manitoba and is part of the Lake Winnipeg Basin. Because of its position on the edge of the Manitoba Escarpment (Figure 1), the watershed drops 180 metres (590 feet) from its western to eastern boundary in less than ten kilometres (six miles). Consequently, lower-lying agricultural lands and infrastructure are particularly vulnerable to flooding and soil erosion caused by snowmelt and heavy rains. Past flooding events have caused significant damage to roads, culverts, bridges and crops.

In the spring of 1979, one snowmelt-runoff event in the watershed flooded over 3,000 hectares (7,400 acres) of land and caused over \$1.2 million in damages. In response, a local farmer organization—the Deerwood Soil and Water Management Association—initiated the construction of over 45 small dams along the Escarpment to reduce peak flow.



Figure 1: Due to the South Tobacco Creek Watershed's position on the edge of the Manitoba Escarpment, lower-lying agricultural lands are particularly vulnerable to flooding caused by snowmelt and heavy rains.

Three types of earthen dams were constructed with funding provided through an agreement administered by federal and provincial governments:

- **Dry flood-control dams** slowly release flood water in a controlled manner (no storage capacity).
- **Back-flood dams** temporarily store shallow waters over a large area of cropped or pastured land for at least two weeks, before the water is released.
- **Multipurpose dams** are similar to dry dams but retain approximately 10-15% of total storage capacity for summer water use.

Twenty-six of these small on-farm dams are located in the South Tobacco Creek Watershed, such that nearly 30% of the watershed's total drainage area is now managed for flow reduction.

The effects of the dams and their reservoirs on flood risk reduction have been studied since the early 1990s, and their impact on sediments and nutrients has been evaluated since 1999. In 2004, this ongoing study was incorporated into the **Watershed Evaluation of Beneficial Management Practices (WEBs)** program—an Agriculture and Agri-Food Canada (AAFC) national initiative. WEBs researchers have continued to evaluate the effects of these structures on sediment and N and P loadings to downstream waters.

How were the small dams and reservoirs evaluated in Manitoba?

Of the 26 dams constructed within the South Tobacco Creek Watershed, two—the Madill and the Steppler dams—were chosen for evaluation as part of the WEBs study (Figure 2).

The Madill *dry flood-control dam* is located in the north-western part of the watershed. It has a 44,500-cubic-metre (36-acre-foot) capacity reservoir and was constructed in 1988.

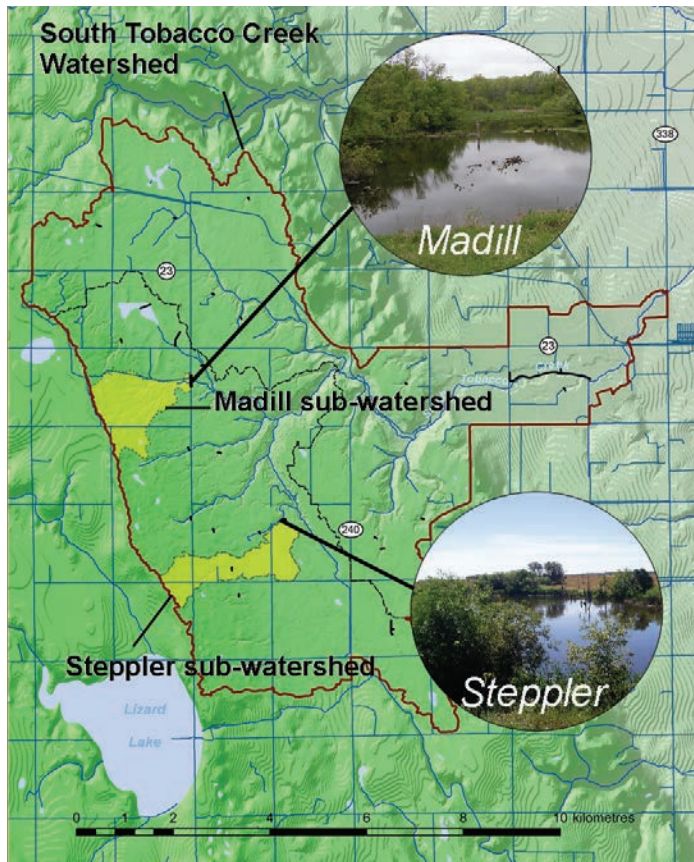


Figure 2: Map of the South Tobacco Creek Watershed, showing the locations of the Madill and Steppler dams.

The Steppler *multi-purpose dam* was constructed in 1986 and has a 50,000-cubic-metre (41-acre-foot) capacity, offering limited year-round water storage (Figures 3 and 4). Located in the south-western part of the watershed, it forms the outlet of the WEBs Steppler sub-watershed.

At the time of construction, the Madill dam cost \$26,000 and the Steppler dam cost \$15,000. Both are estimated to have a fifty-year lifespan.



Figure 3: Steppler reservoir with high flood-retention levels (~ 40,000 m³). The water level meter is virtually submerged (lower right of photo).



Figure 4: Steppler reservoir with low water levels (~ 4,000-5,000 m³). The water level meter is visible in the foreground.

Water quality sampling for sediment and nutrients at the Steppler and Madill dams was performed in conjunction with flow measurements. An auto-sampler collected inflow samples upstream of each reservoir as the water level rose in the stream, and at timed intervals. Reservoir outflow was sampled manually as the water exited each structure (Figure 5).



Figure 5: Manual water quality sampling immediately downstream of the Madill dam.

What is WEBS?

A long-term research program initiated in 2004 by Agriculture and Agri-Food Canada, Watershed Evaluation of Beneficial Management Practices (WEBS) evaluates the economic and environmental performance of beneficial management practices (BMPs) at a watershed scale. To gain a regional perspective, this information is being scaled up to larger watershed areas using hydrologic models.

WEBS findings are helping researchers and agri-environmental policy and programming experts

understand how BMPs perform and interact with land and water. This knowledge will also help producers determine which BMPs are best for their operations and regions.

WEBS studies are conducted at nine small watershed sites across Canada. These outdoor living laboratories bring together a wide range of experts from various government, academic, watershed and producer groups. Many valuable findings have emerged and research continues at all sites.

What effect did the small dams have on peak flow and water quality?

The two dams successfully reduced peak flow as runoff was routed through their reservoirs. As intended, little of the overall runoff volume was retained in the reservoirs. Collectively, it is estimated that the entire network of 26 small dams reduced peak flow due to snowmelt by 9-19% and rainfall runoff by 13-25%. These results are for runoff frequencies ranging from a 1 in 2-year event to a 1 in 100-year event.¹

Figure 6 depicts the average annual percentage reductions in flow, sediment and various forms of N and P for the Steppeler and Madill dams. It shows that, despite differences in construction, both reservoirs significantly reduced not only the export of sediment, as expected, but also the export of total N and total P. This reduction occurred during both snowmelt- and rainfall-generated runoff events.

During rainfall, the reservoirs were occasionally sources of particulate P (average annual increase of 3% for Steppeler and 15% for Madill). However, since dissolved nutrients are the year-round dominant form of N and P in this watershed (> 70% each—data not shown), the two reservoirs were successful in reducing total N and P loads overall.

Ongoing research is investigating why both types of reservoirs are so effective at removing nutrients.

¹ Yarotski, Jim. June 1996. Canada-Manitoba Soil Conservation Agreement, Program 6, South Tobacco Creek Pilot Project: Effects of Headwater Storage on Runoff Peaks, Hydrology Report #142. PFRA/AAFC.

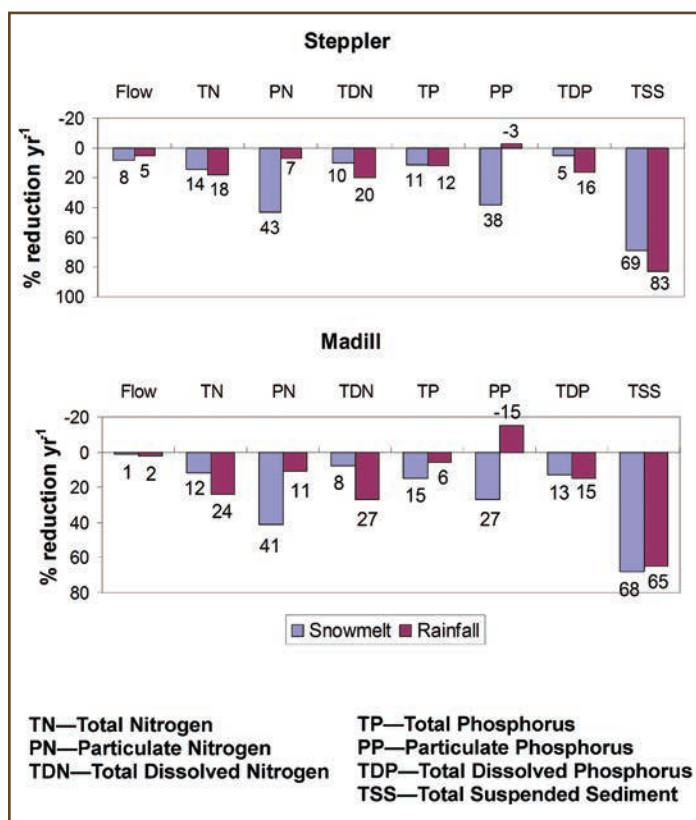


Figure 6: Average annual reduction in downstream (dam outlet) peak flow, sediment and nutrient export during spring snowmelt and summer rainfall events at the Steppeler and Madill dams (1999–2007).

Economic and modelling implications

The small dams in the South Tobacco Creek Watershed have the clear potential to regulate peak flow and thereby directly benefit those landowners who live within the watershed. Additionally, some of the dams may provide back-flood irrigation or have the storage capacity to serve as livestock watering sources.

Although these small dams are largely located on private property, they also provide a public benefit by mitigating downstream flooding and sediment loading. In addition, it is possible that the nutrient reductions that have been measured at the outlet of the dams could be reflected further downstream—at the watershed outlet or beyond. Should this prove to be the case, the construction and operating costs of the dams may be further offset by these public benefits.

Conclusion

In combination with improved flood and erosion control, it is clear that small headwater storage dams are an effective conservation tool that may also reduce downstream nutrient loading into rivers and water bodies. This BMP should merit consideration by watershed managers and policy makers when developing resource protection plans, particularly for agricultural escarpment regions on the Great Plains.

A hydrologic computer model—based on an adapted version of SWAT (Soil and Water Assessment Tool)—has been developed and validated for the South Tobacco Creek Watershed. The model is being used to predict the impacts of the dams at varying landscape scales as well as under a variety of climate and land-use scenarios (such as different farming practices or interactions with other BMPs).

As well, the South Tobacco Creek project is one of two WEBs integrated modelling pilot studies underway whereby hydrologic modelling variables are coupled with economic and social variables. The resulting models will act as decision-support tools towards identifying: optimum BMP location for environmental benefit; likelihood of producer adoption; and cost ranges for construction and maintenance. These WEBs modelling activities are geared towards providing valuable insights into quantifying on-farm and downstream BMP effects.



View from the top of the Manitoba Escarpment, looking downslope to the east.

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AAFC leads the national WEBs program and provides funding under its Growing Forward initiative. Ducks Unlimited Canada has been a key contributing partner. Other partners at the South Tobacco Creek project include: Deerwood Soil and Water Management Association; Environment Canada; Fisheries and Oceans Canada; Manitoba Agriculture, Food and Rural Initiatives; Manitoba Water Stewardship; University of Manitoba; University of Guelph; and University of Alberta.

For more information on WEBs please visit www.agr.gc.ca/webs or contact WEBs at webs@agr.gc.ca.