Flood Flow Contribution of the Upper Otter Tail River Watershed

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DNR Ecological & Water Resources

DNR Information Center

Twin Cities: (651) 296-6157
Minnesota Toll Free: 1-888-646-6367 (or 888-MINNDNR)
Telecommunication Device for the Deaf: (TDD): (651) 296-5484
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DNR Ecological & Water Resources
500 Lafayette Road
St. Paul, MN 55155-4032
(651) 259-5700

Web Address: mndnr.gov/waters

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The significant public and private damages, cost of flood fights, and disruptions to commerce and daily life as the result of the frequent flooding within the Red River basin are well known. Likewise, the factors contributing to the frequent floods have been well-documented.

To address the flood threat, levees have been constructed to protect many Red River basin communities and farmsteads. The preferred flood damage reduction option for the Fargo-Moorhead area is a large diversion channel. These measures provide a certain level of protection, but are not guaranteed to protect communities against all future floods.

Temporarily holding back excess runoff throughout the watershed – impoundments, wetlands, culvert sizing - not only provide local flood damage reduction benefit, but if designed and operated correctly, may provide main stem benefits as well. These measures can offer an additional layer of protection to those areas served by levees and diversion channels.

One storage scheme identified by local interests is to use lakes within the Otter Tail River watershed as temporary flood impoundments. The "natural" storage provided by the lakes and wetlands within the Otter Tail River watershed already provides significant flood damage reduction benefit to downstream lands and communities. But the theory is that lake levels, and therefore outflow, could be manipulated to further reduce downstream flooding. Infrastructure costs would likely be modest as many lakes are already controlled by outlet dams.

This paper will address the feasibility of active lake level management to provide downstream flood damage reduction benefits by looking at the history of lake level control, opportunities, and flow and lake level data from recent floods.

History of Lake Outlet Control

During the 1930s and early 1940s, over three hundred lake outlet dams were constructed throughout Minnesota by the Works Progress Administration (WPA). At that time, many lakes were at historic low levels due to the severe drought of the 1930s. Following construction, the dams were turned over to the then MN Department of Conservation, now the Department of Natural Resources.

The WPA dams were generally constructed with operable features – typically stop logs. The design philosophy was that during "normal" climatic conditions, stop logs would be added or removed from the dam in order to control the amount of water flowing out of the lake and thereby maintain a targeted lake level. During periods of high precipitation and/or snowmelt, sufficient stop logs would be removed from the dam such that the outlet and therefore the lake would be in a "state of nature." That is, the dam would no longer control lake levels. Following construction, a local operator was hired to add and remove stop logs and keep a record of actual lake levels.

A few years' experience found that this concept works much better in theory, than practice. Then as is true today, climate conditions are the predominant factor affecting lake levels. During the 1940s climate changed dramatically from drought to wetter than average conditions. Regardless of the skill and diligence of the operator, it was typically not possible to maintain a target lake level, much less identify a level that all lakeshore owners could agree is appropriate.

In 1947 the decision was made to discontinue operation of the WPA-constructed dams. Instead of defining a target lake level, the height of a dam was permanently set at a prescribed level. The dams still held back water to help minimize low levels, but lake levels were left to respond to the prevailing climate trends.

DNR Waters has a long institutional memory and very thick correspondence files dealing with lake level issues throughout the state. Many lakeshore owners are very passionate about their lakes; any proposal to modify a lake outlet often brings out that passion. The same story has been told many, many times on lakes throughout the state. The DNR therefore has a strong bias against active manipulation of lake levels on recreation lakes. This bias is reflected in Minnesota statute and the rules and regulations for the permitting of new or modified dams.

Minor changes have periodically been made to a lake outlet, but only after careful consideration and analysis. A brochure has been prepared that documents the general steps needed to affect a change to a lake outlet. http://files.dnr.state.mn.us/publications/waters/lake_outlet_dams.pdf

Laws and regulations may be changed. Much less certain is whether all lakeshore owners would willingly accept greater lake level fluctuation that may or may not benefit distant communities.

Opportunities

The Otter Tail River watershed contains over 1300 lakes; 37 of those lakes are greater than 1000 acres in size. Many lakes are landlocked, and therefore do not contribute any surface runoff to the Red River. But most of the lakes do have an outlet channel, and therefore have the potential to store more runoff.

The vast majority of lakes within the Otter Tail River watershed do not have an outlet dam. A dam would therefore need to be constructed at the outlet of these lakes in order to temporarily detain additional runoff in anticipation of a flood event. Building a dam to impound water would require flowage easements from all affected private land owners since higher levels would result. On smaller lakes, this may involve a few dozen owners; there may be hundreds if not thousands of land owners on larger lakes. This cannot be considered a feasible option as obtaining the necessary flowage easements would be nearly impossible.

Only a few dozen lakes within the watershed are controlled by an outlet dam. A likely candidate would be Otter Tail Lake, a large lake (12,000 acres) located roughly in the middle of the watershed. The dam is owned by DNR Waters and was reconstructed in 1993 without any operable features. Otter Tail Lake will fluctuate during a large runoff event on the order of one to two feet. This represents a very large volume of water that is already temporarily stored on the lake.

Additional storage volume could be obtained by either drawing down lake levels prior to an anticipated flood, and/or holding more water back during the flood event. In theory it's possible that a plan could be devised that would optimize the operation of outlet dams among a handful of larger lakes, such as Otter Tail Lake to

work in conjunction with the operation of the Orwell Reservoir by the U.S. Army Corps of Engineers. Data and analytical tools are available to do this type of analysis.

The amount of potential draw down is dependent on the hydraulic capacity of the downstream channel, and the difference in the height of water levels on the upstream and downstream sides of the outlet dam. On many lakes controlled by a WPA-constructed dam, including Otter Tail Lake, the maximum drawdown potential would be one foot or less. When the following photograph of the Otter Tail Lake dam was taken in February 1998 (Figure 1), the lake level was approximately six inches above the water level in the downstream channel.

Figure 1. Otter Tail Lake Dam.

Before going too far down this path, it would be instructive to look at the available measured stream flow and lake level data recorded during past floods. These data provide the best source of information to assess the relative contribution of the Upper Otter Tail River watershed lakes region to the peak flood flows on the Red River. These data also provide a sense as to whether this strategy might result in significant benefit – focusing on the Fargo-Moorhead area – and therefore warrant additional study.

Stream Flow Information

Stream flow data are measured at many locations throughout the Red River basin by many units of government. The U.S. Geological Survey (USGS) is the primary source of data for the Red River and major tributaries. The location of four USGS stations is shown in Figure 2.

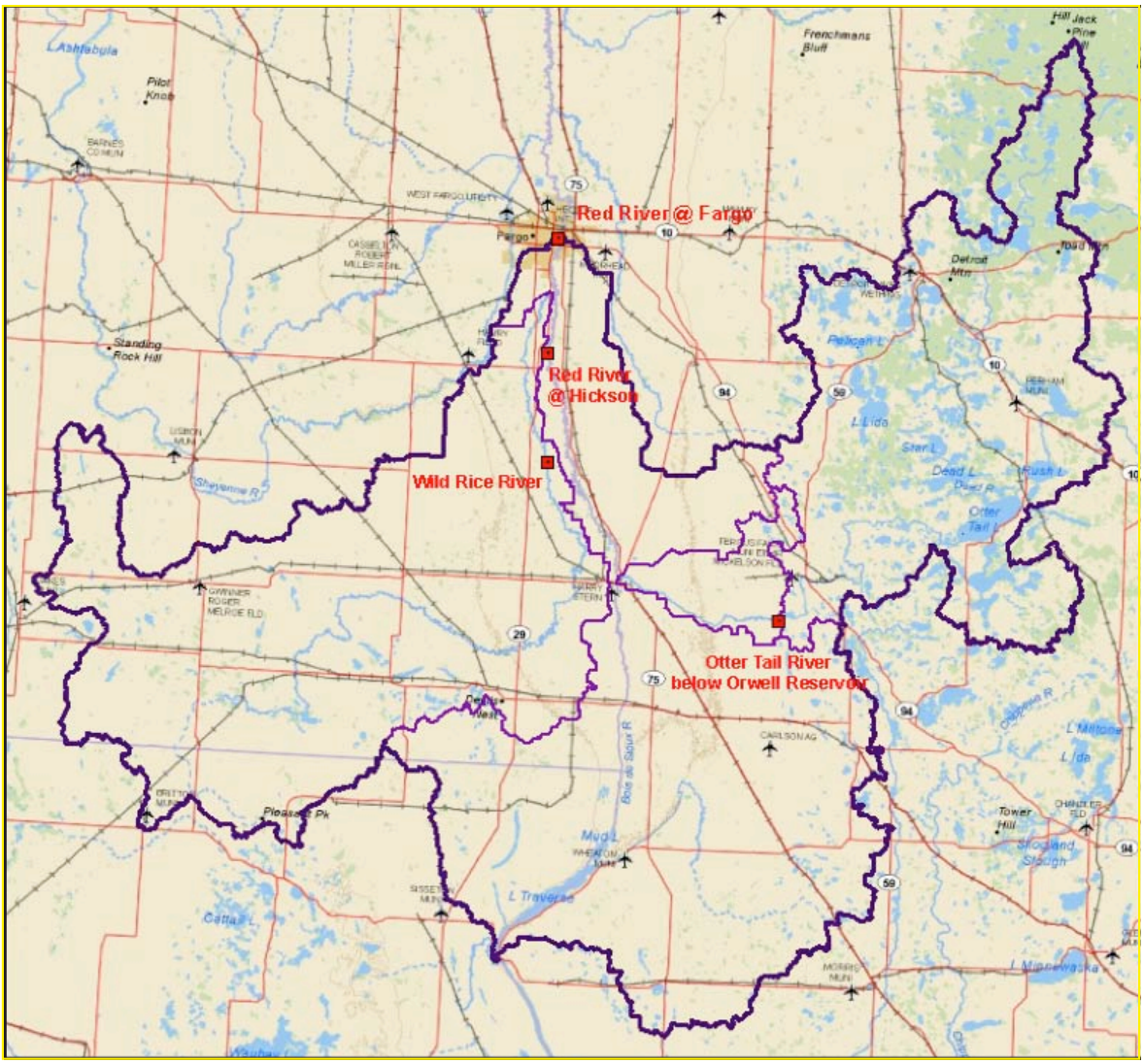


Figure 2: Location of four U.S. Geological Survey stream gaging stations within the Red River watershed upstream of Fargo.

Recorded flow data from these stations for the 1997 and 2009 floods are plotted in Figures 3a and 3b. The majority of the flood flow of the Red River at Fargo comes from the upper Red River (which includes the Bois de Sioux River and Otter Tail River watersheds), with a slightly smaller contribution from the North Dakota Wild Rice River. The shape of the Red River at Hickson and Wild Rice River hydrographs is similar to the shape of the Red River at Fargo hydrograph.

While the Otter Tail River upstream of the Orwell Reservoir represents 26% of the total watershed area at the Fargo stream gage, during the 1997 and 2009 floods it contributed just 5% of the peak flow. The Upper Otter Tail River hydrograph does not have a pronounced peak, characteristic of watersheds having a large amount of storage. The Otter Tail River hydrograph also reflects the influence of the Orwell Reservoir on reducing peak flows.

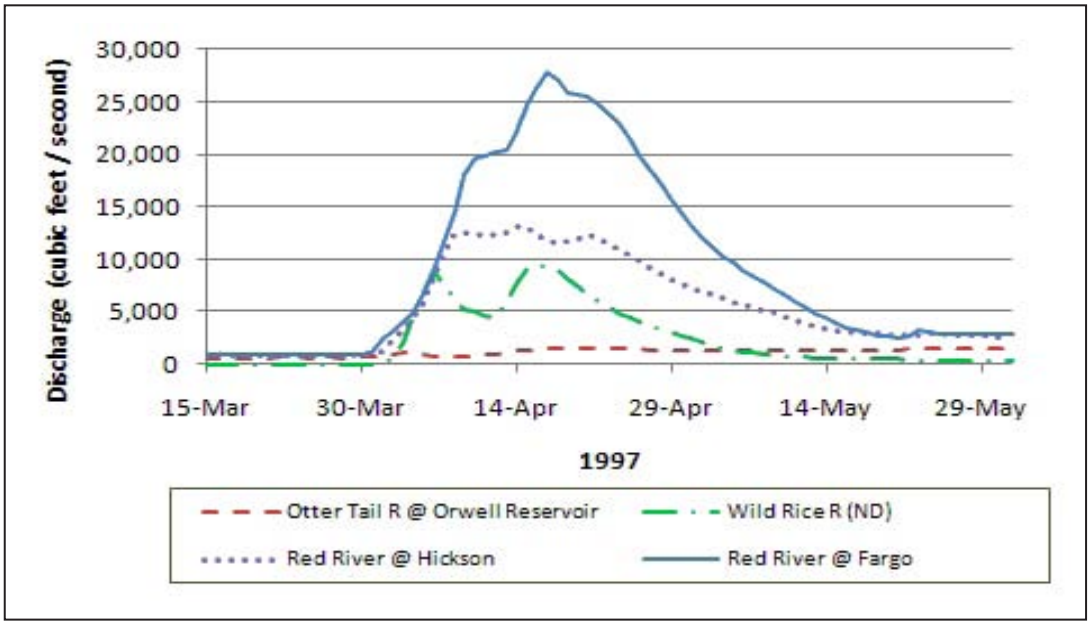
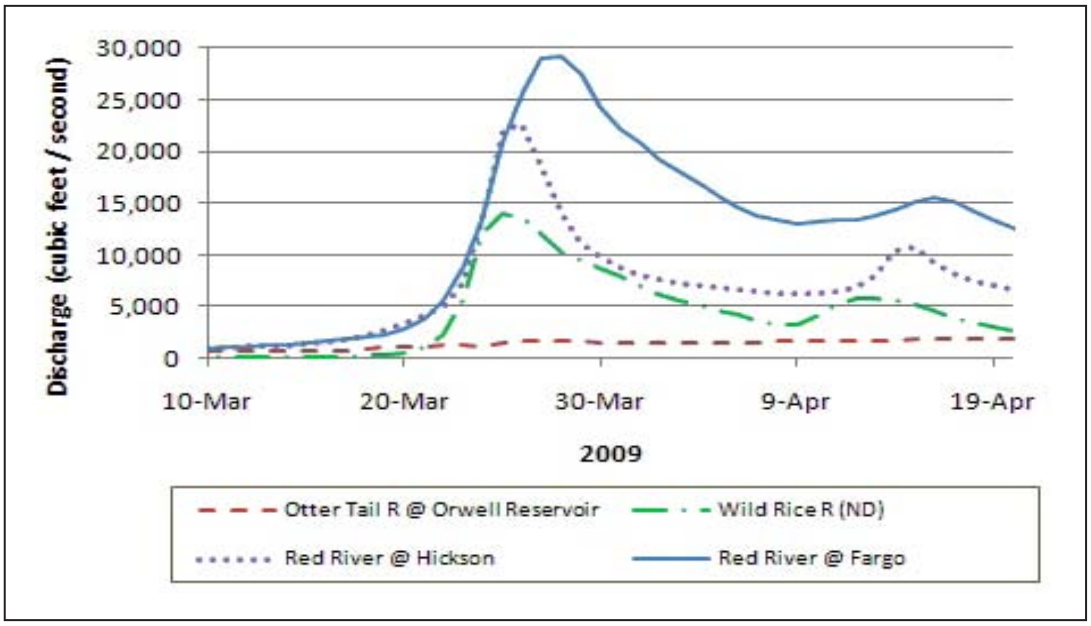


Figure 3a: 1997 flow hydrographs @ four USGS gaging stations



Figures 3b: 2009 flow hydrographs @ four USGS gage stations

Recorded Lake Level Information

The stream flow information presented above shows that the portion of the Otter Tail River watershed upstream of the Orwell Reservoir contributes a very small percentage of the peak flow of the Red River at Fargo. We can also examine recorded lake level data during the recent major floods.

Recorded lake level data are available for the early spring period on Pelican and Otter Tail Lakes. Their combined watershed area represents nearly 68% of the total Otter Tail River Watershed (Figure 4). Lake level data are plotted with Red River at Fargo flow data in Figures 5a and 5b. These data show that peak lake levels, and therefore peak outflow, on Otter Tail and Pelican Lakes occur three to four weeks after the flood peak at Fargo.

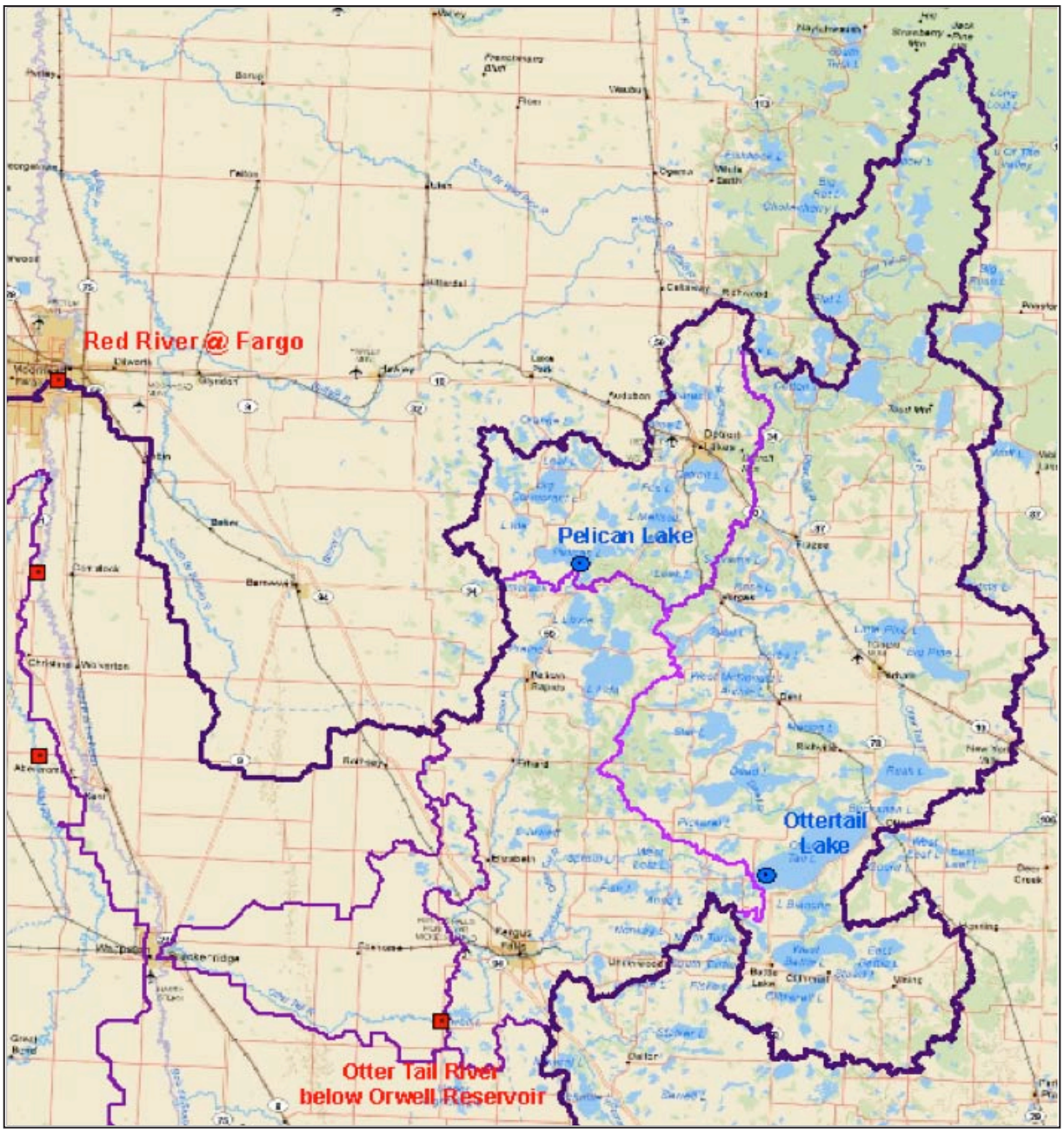


Figure 4: Otter Tail River Watershed, including the Orwell Reservoir, Otter Tail Lake and Pelican Lake subwatersheds.

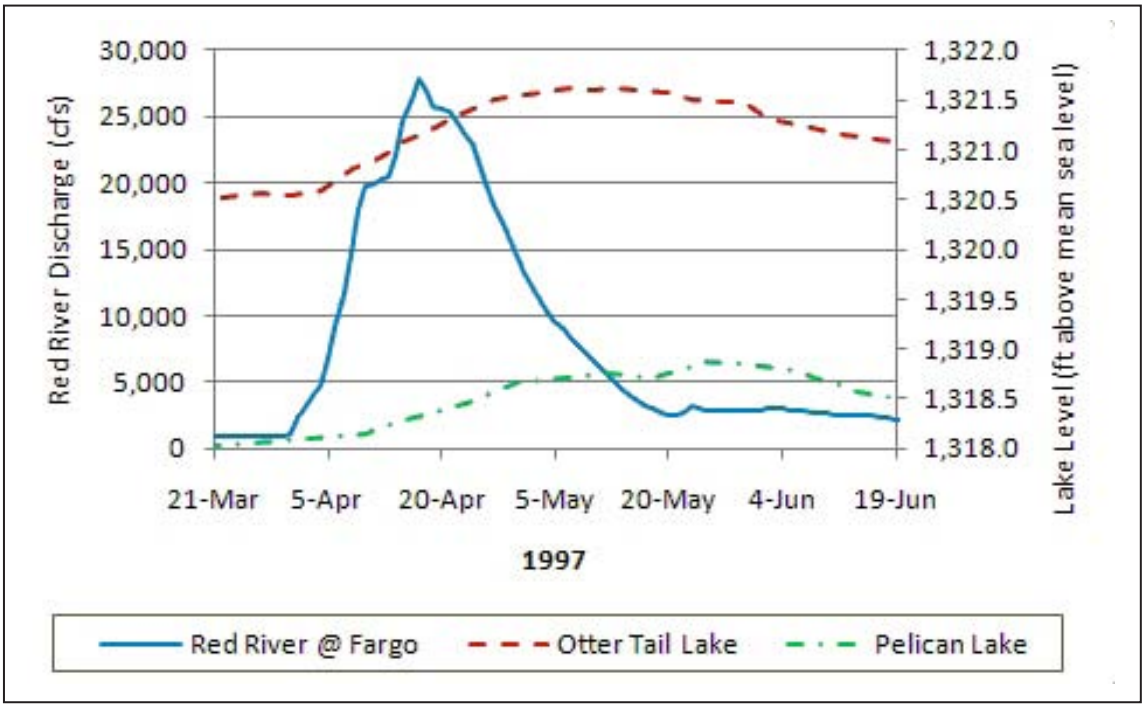


Figure 5a: 1997 flow and lake level hydrographs

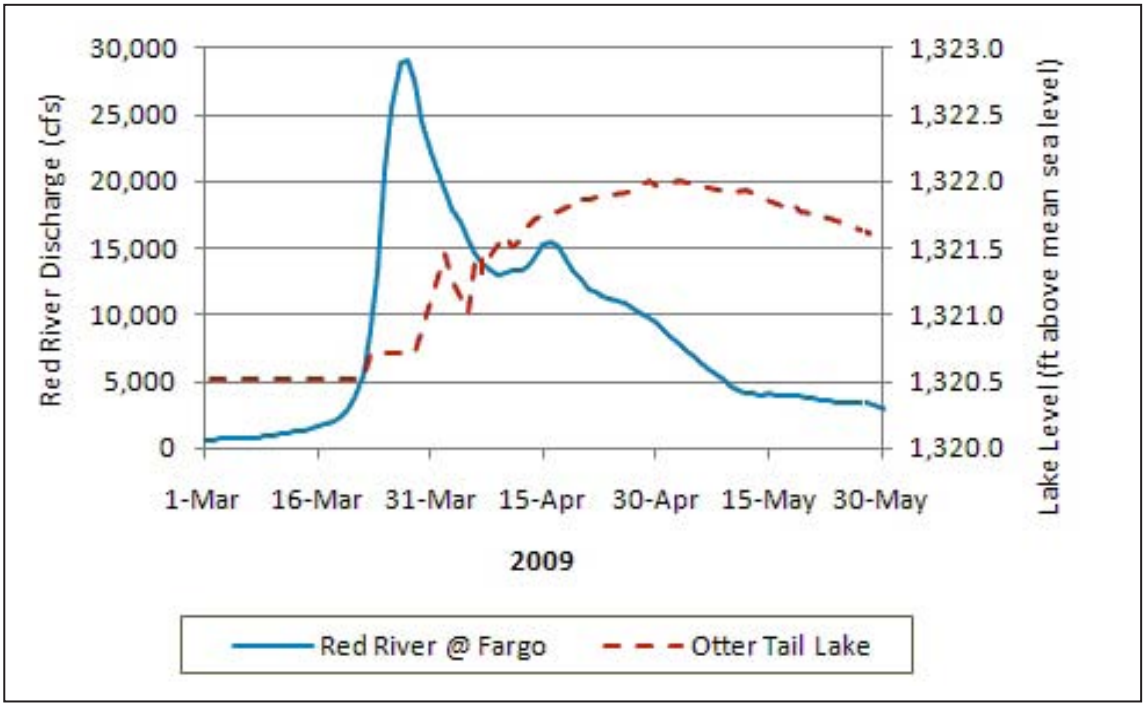


Figure 5b: 2009 flow and lake level hydrographs

There would be two basic options to increase the amount of flood storage on either of these two lakes. The first option would be to release water prior to the flood event in order to draw down lake levels and thereby create additional storage. For this scheme to work it would be necessary to release water well before the actual flood event, most likely in January and February. This is due to the considerable distance and therefore the time it takes water to flow from the lakes to the Red River and then downstream of the damage centers. (Otter Tail Lake is nearly 200 stream miles upstream of Fargo-Moorhead.)

This early release of water would also have to occur before the U.S. Army Corps of Engineers releases water from the Orwell Reservoir – typically in March. Releasing water from upstream lakes too late may actually increase downstream flooding. The other risk is that if the anticipated high spring runoff does not occur, affected lakes may not return to "normal" summer levels.

The second option would be to restrict outflow from selected lakes, say one to two weeks before the anticipated crest on the Red River. This would result in higher lake levels than otherwise would have occurred, with the potential for increased damages to properties around the lake and adverse environmental impacts. This option would require flowage easements from all lakeshore owners – definitely not a feasible alternative. While it is technically possible that a plan could be devised to hold additional runoff on Otter Tail River watershed lakes, whether it is practical to do so is another matter.

Other Storage Options

The lakes region of the Otter Tail River watershed already provides significant flood damage reduction benefits to Breckenridge and Fargo. Any attempt to manipulate lake levels in this region would have a very limited incremental downstream flood damage reduction benefit.

Reducing Red River flooding can be achieved by storing runoff from lands that do contribute significant runoff to the Red River. The Bois de Sioux Watershed District recently completed one impoundment project (North Ottawa within the Rabbitt River subwatershed), and is developing plans for a second similar project (Redpath within the Mustinka River watershed). Based on recent model studies by the engineer for the Bois de Sioux Watershed District, the peak flow at Fargo would have been 3.1% lower had these two impoundments been operational during the 1997 flood.

Projects like these are not without significant issues and potential controversy, including permitting, land owner acceptance, natural resource impacts, and funding. But the North Ottawa project demonstrates these types of projects are possible, and that they provide significant local benefit, as well as main stem benefits.

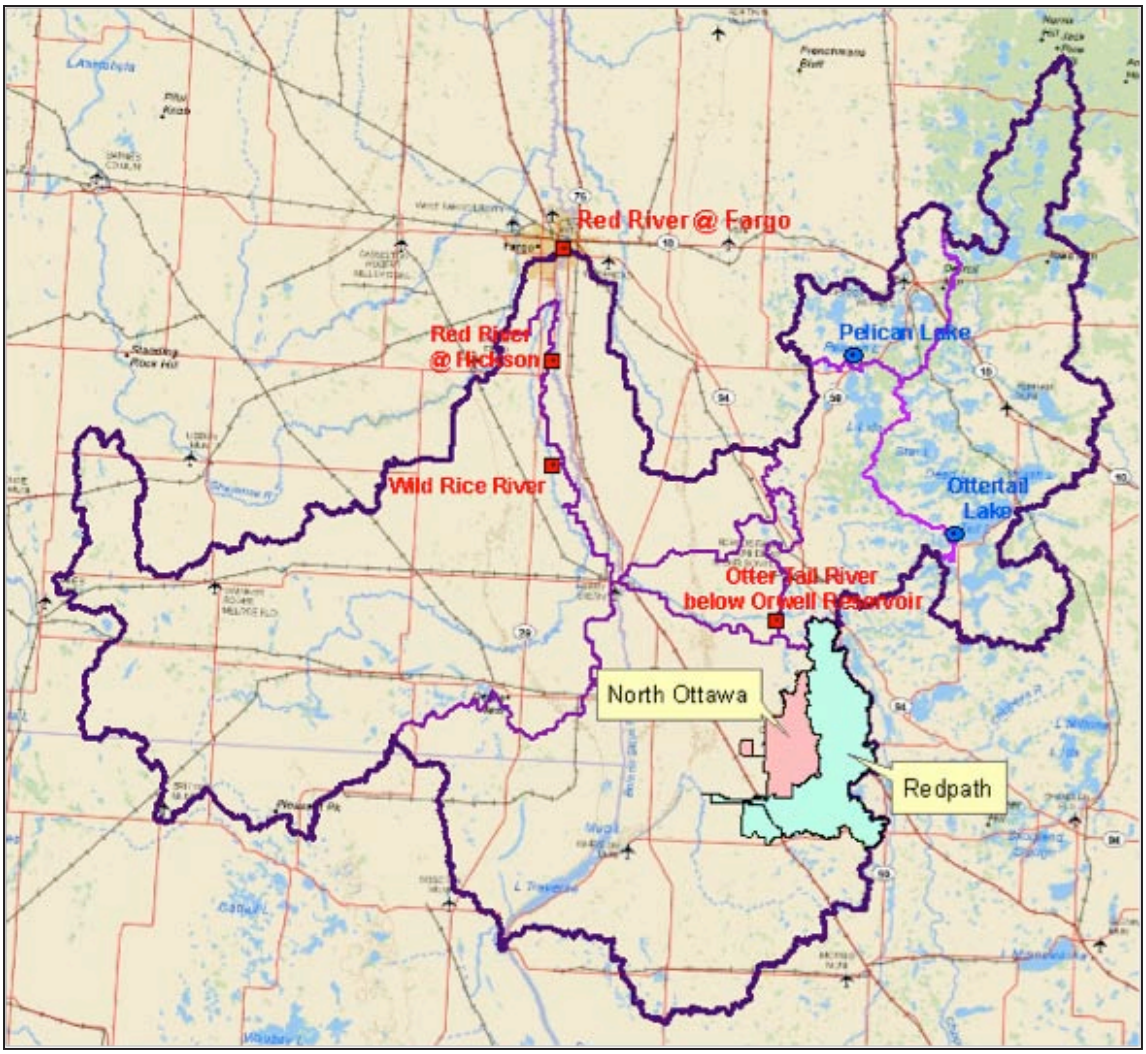


Figure 6. The Red River @ Fargo watershed, with the watershed areas for the recently completed North Ottawa flood impoundment project and for the proposed Redpath project.

Summary

The lakes region of the Otter Tail River watershed already provides significant flood damage reduction benefits to Red River main stem communities.

- Flow contribution of the upper Otter Tail River watershed is a very low percentage of the total peak flood flows on the Red River.

- Peak flows out of the lakes region of the upper Otter Tail River watershed occur two to four weeks after peak flows at Fargo.

Any attempt to manipulate lake levels in this region would have negligible downstream flood damage reduction benefits.

Increasing the storage opportunities on recreational lakes has practical limitations, including limited hydraulic capacity of the outlet channel, their long distance upstream of Red River damage centers, land owner acceptance, and the likely need to obtain flowage easements.

Other feasible options exist to store runoff that will have much greater local flood damage reduction benefit, as well as main stem benefits.