Impoundments are projects that store flood water. There are many possible variations in the design of impoundments and each site presents a unique set of problems and opportunities.

As with any project, the goals are to maximize the positive and minimize the negative impacts. In addition to flood control, potential benefits include erosion control, sedimentation, wetland development, stream flow maintenance, water supply, lake improvement, and recreation. In addition to direct cost, potential negative impacts include obstruction of fish migration, interruption of riparian corridors, unnatural stream flow regimes, sediment transport imbalance, loss of base flow, conversion of wetlands, and other vegetative changes.

Because of the wide variety of impacts there is a need for a multi-disciplinary approach. Proper site selection and design are critical.

Site Considerations

Sites with significant existing environmental or social values may present special problems when attempting to develop impoundment projects.

Site selection should consider compatible use relative to total watershed management objectives. Flood control, habitat preservation, connectivity, biodiversity, economic land uses, community stability, legal rights and social needs should all be considered. Achieving objectives that fully satisfy all public interests may be impossible. Yet, by following basic guidelines much controversy can be avoided.

Previously disturbed sites may be the most suitable for flood control impoundments. Best candidates may include drained or poorly drained wetlands, flood prone croplands, irregularly shaped fields, or other difficult to farm areas.

Sites with significant existing environmental or social values such as stable natural stream channels, virgin native prairie, unaltered natural wetlands or historical preservation areas deserve
eliminated its major contribution to the 1997 spring flood peaks along the Red River. That, along with 75,000 acre-feet of gated storage in the remainder of the Bois de Sioux watershed, would have prevented the disaster that occurred at Breckenridge and the major flooding that occurred at Moorhead. 50,000 acre-feet of additional flood storage in the Thief River watershed might have controlled flooding on that tributary. This along with about 100,000 acre-feet of gated storage in the remainder of the Red Lake River watershed would greatly reduce the flood threat at Crookston. 65,000 acre-feet of un-gated storage has been proposed on the Maple River in North Dakota.

If the remaining tributaries require similar flood storage to those mentioned above, it would appear that the volume of storage required on the tributaries is about equal to what is required to provide flood control on the Red River.

**Location and Timing**

Location of an impoundment within a watershed is an important factor in determining its potential for providing flood control benefits. Location, and other timing factors, are also important in determining appropriate design.

In a simple watershed with only one flood damage center, the hydrologically ideal impoundment location would be immediately upstream from the damage center. The design parameters are also relatively simple. The outlet should be sized to pass flows within the tolerable downstream limits and the impoundment should be large enough to store the excess.

If there is no suitable site immediately upstream from the damage center, impoundment site selection and design become more complicated. Areas that consistently contribute high flows to downstream flood peaks present the greatest opportunity for impoundment benefits. Conversely, areas that consistently pass flows ahead of the flood hydrograph may be poorer locations for an impoundment. Impoundments on lower tributaries can actually increase downstream main stem flood peaks if water stored early is released during the downstream flood peak.

When one damage site is downstream from another damage site the problem is further complicated. The ideal location becomes a compromise between what would have been best for each individual damage site. Because storing early water is counterproductive, the safest compromise locations tend to be within the middle to upper areas of the watershed. Sites in early water areas relative to one of the damage sites must be very carefully designed or operated to avoid increasing flood flows at that location.

When a basin such as the Red River has multiple damage centers and is climatologically large, the problem becomes extremely complicated. Timing factors other than location, such as weather, play very important roles. Optimum flood control requires large storage capacity and
water into the impoundment from a higher elevation. Impoundments of this type often have dikes on all four sides and a diked inlet channel. The advantages of this type are that they may require less land, and storage can occur while flow in the channel is at or below flood stage.

**Gated vs Ungated**

Impoundments may have *gated* outlets, which can be operated in response to conditions anywhere in the watershed, or *ungated* outlets, which release a designed amount of water based on the elevation of water in the reservoir.

Gated outlets provide greater flood control benefits because the timing and amount of storage and release can be adjusted based on existing or predicted conditions downstream in the watershed. They may also result in less adverse impacts within the flood pool area because water is normally stored only when necessary or beneficial and can be quickly released after downstream flooding conditions have subsided. Gated outlets allow a wider range of control which provides the enhanced flood control, but also may result in more abrupt and significant changes in downstream flows. This may negatively impact the stream environment. But those impacts should occur infrequently and only during major flood events.

Most gated impoundments also include ungated outlets as emergency spillways for dam safety when the design capacity of the reservoir is exceeded.

Types of outlets include weirs and orifices. Weirs are overflow devices. Because outflow increases rapidly with increasing stage, weirs are used where level control is the primary concern. Orifices are underflow devices. Because outflow varies less with increasing stage, orifices are used where flow control is the primary concern. An impoundment outlet may include both weirs and orifices and both devices may be gated or ungated. An example of a gated weir would be a stoplog bay. An example of a gated orifice would be a sluice gate.

Gate control is most beneficial when timing of storage and release are critical. This is often the case when the flood is of long duration and when the location of the storage is far upstream from a point of flood control interest. If water from an area would precede the downstream flood peak, storage would not be advisable and the gate should be open. It should be closed to avoid contributing to peak flows and kept closed until flood conditions have subsided. Because gated storage is more efficient, it should always be considered when flood storage capacity within the watershed is limited.

The main disadvantages of gate control are the potential for improper or unauthorized operation and added expenses of operation. The larger the impoundment the more practical gate control will be.
The most beneficial locations would be within the watersheds of intermittent streams that have potential for high quality stream habitat and upstream from potential high value water users.

The design goals include minimizing reservoir evaporative losses and providing high quality water. Evaporative losses are proportional to surface area. Therefore, deep reservoirs with relatively smaller surface areas are preferred. Desirable water quality features include sedimentation of incoming suspended solids, minimal resuspension of sediments, adequate dissolved oxygen, and suitable trophic conditions. In general, water quality is also better in relatively deep reservoirs.

Reliable water supply can be provided without significantly detracting from flood control if the retained amount is limited to what is normally available on an annual basis. As an example, assume that a reservoir has capacity to store 3.7" of runoff from its watershed area, which is typical of a 10 year spring flood. If 1" of runoff is retained, the reservoir would still have capacity to store all of a typical summer 100-year, 24 hour rainstorm runoff of 2.6". In an average year, the 1" of runoff that is retained would be used for water supply and stream flow maintenance. If greater reservoir capacity is available, some water could be carried forward from year to year as a drought contingency.

The amount of water normally available for water supply would depend on pool losses. If half the water were assumed to be lost, the remainder could still provide a continuous outflow of 3.5 cfs from a 100 square mile watershed.

**Flood Control Wetland Impoundments**

Impoundments can be designed to incorporate wetland benefits. Additional design goals include a semi-permanent wetland pool and control of pool bounce.

The size and depth of the wetland pool would depend on the type of wetland desired. In general, wetlands are relatively shallow water bodies. The size of the wetland is dictated by topography and may be limited by the availability of water to replenish evaporative and seepage losses. Assuming a pool drawdown of 2 feet by spring, the level could be restored by 1 to 2 inches of runoff from a watershed 12 to 24 times the size of the wetland. If the watershed to pool ratio is less than 10, there is likely to be a significant pool deficit in drier years. If the watershed to pool ratio is much greater than 20, the pool may be subjected to high bounce during summer runoff events.

Pool bounce may adversely impact nesting wildlife and wetland vegetation. It is desirable to keep bounce to a minimum during frequently occurring summer runoff events. This can best be
Summary

Impoundments can provide substantial flood control benefits if properly located and designed. Proper location and design can also help to avoid or minimize adverse environmental impacts. Opportunities exist for projects that provide multiple benefits. Partnership in addressing flood control and other environmental issues may result in the most cost effective and beneficial solutions.