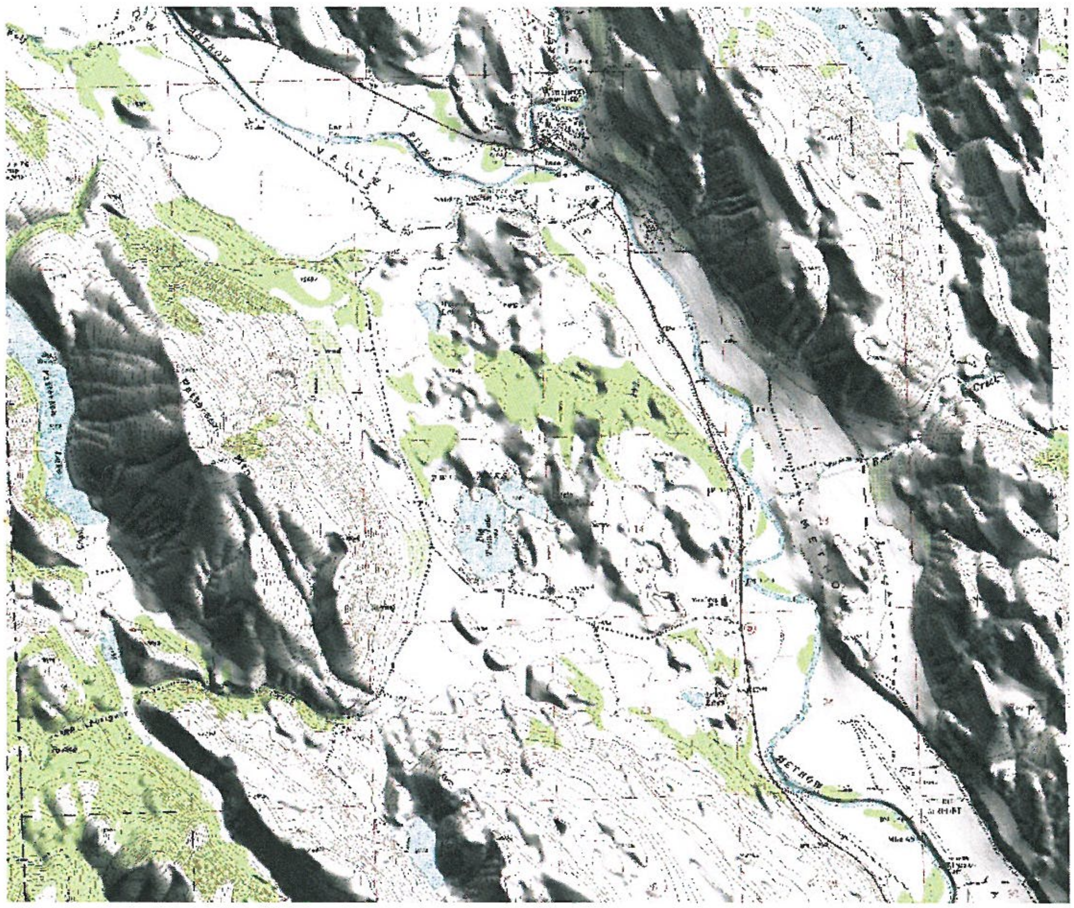
Twin Lakes Aquifer Recharge Project
Final Interim Report



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Presented to:

Twin Lakes Aquifer Coalition
Washington Dept. of Ecology
Washington Dept. of Fish and Wildlife
Washington Legislature

Executive Summary

Groundwater levels in the Twin Lakes Aquifer (Aquifer) have dropped by as much as 11 feet since 1999. The declined has impacted Twin Lakes fisheries as well as its recreational value. Also it has adversely affected more than 500 home sites that rely on this aquifer for their source of water. A municipal water supply system for these affected users is impractical and would take years to build.

This precipitous decrease in water levels has been caused by two factors:

- A decrease in aquifer recharge due to state-enforced changes on the Wolf Creek Reclamation District's operations and
- Less than average precipitation.

In this study, we have identified that the man caused changes are responsible for more than half of the water level decline. We believe that without an immediate and sustained recharge program, water levels will further decline and the Aquifer will be unreliable as a water supply. In addition, the recreationally important Twin Lakes fisheries will vanish with the declining lake levels.

To combat this situation the Twin Lakes Aquifer Coalition secured funding from the Washington Department of Ecology to seek engineering answers for the declining water levels.

Fortunately, there are answers. There are potential sources of water that can remedy this situation. And equally important, there is a wide, diverse coalition of support for several of the available options.

In this report, seventeen potential measures were evaluated. They generally consisted of adding more water to the Aquifer through gravity or by pumping. The sources of water included additional water from Wolf Creek, efficiency savings in the Wolf Creek Reclamation District, Thompson Creek drainage, and from the Methow River. We believe that the best measure is to re-route the under-used Thompson Creek drainage to recharge the Aquifer. In addition, paying for groundwater pumping for a couple of water users and using their irrigation rights in exchange, will be required to recharge the Aquifer. This groundwater pumping exchange program will be required for about five years.

There are several places that the Aquifer can be recharged. A good location is at Barnsley Lake where the increased level of this lake will recharge the Aquifer in its full extent. Another good location is a sink hole just to the southwest of Big Twin Lake. Other locations, including directly into Twin Lakes, may also be acceptable.

The preferred option is to utilize a Thompson Creek Diversion along with Temporary Water Rights Transfers. These measures result in a total project cost of **$248,000**.

If the Thompson Creek measure proves to be unreliable (we don't know very much about the hydrology of this stream), the Thompson Creek diversion would be scrapped and the second preferred option, increasing the diversion at Wolf Creek, would be implemented. The project total for this option would be approximately **$443,000**.

A third option, pumping water from the Methow Valley Aquifer, would have a project total of approximately **$340,000** to **$505,000**. The lesser amount is if water could be introduced solely at Barnsley Lake.

1. Introduction

The Twin Lakes Aquifer (Aquifer) is located approximately 2 miles south of Winthrop, Washington. The Aquifer is approximately 4.6 square miles in size and includes the area of Twin Lakes and Barnsley Lake (Figure 1). In its vertical extent, it consists of as much as 230 feet of glacial deposits that lay on Methow River valley sediments.

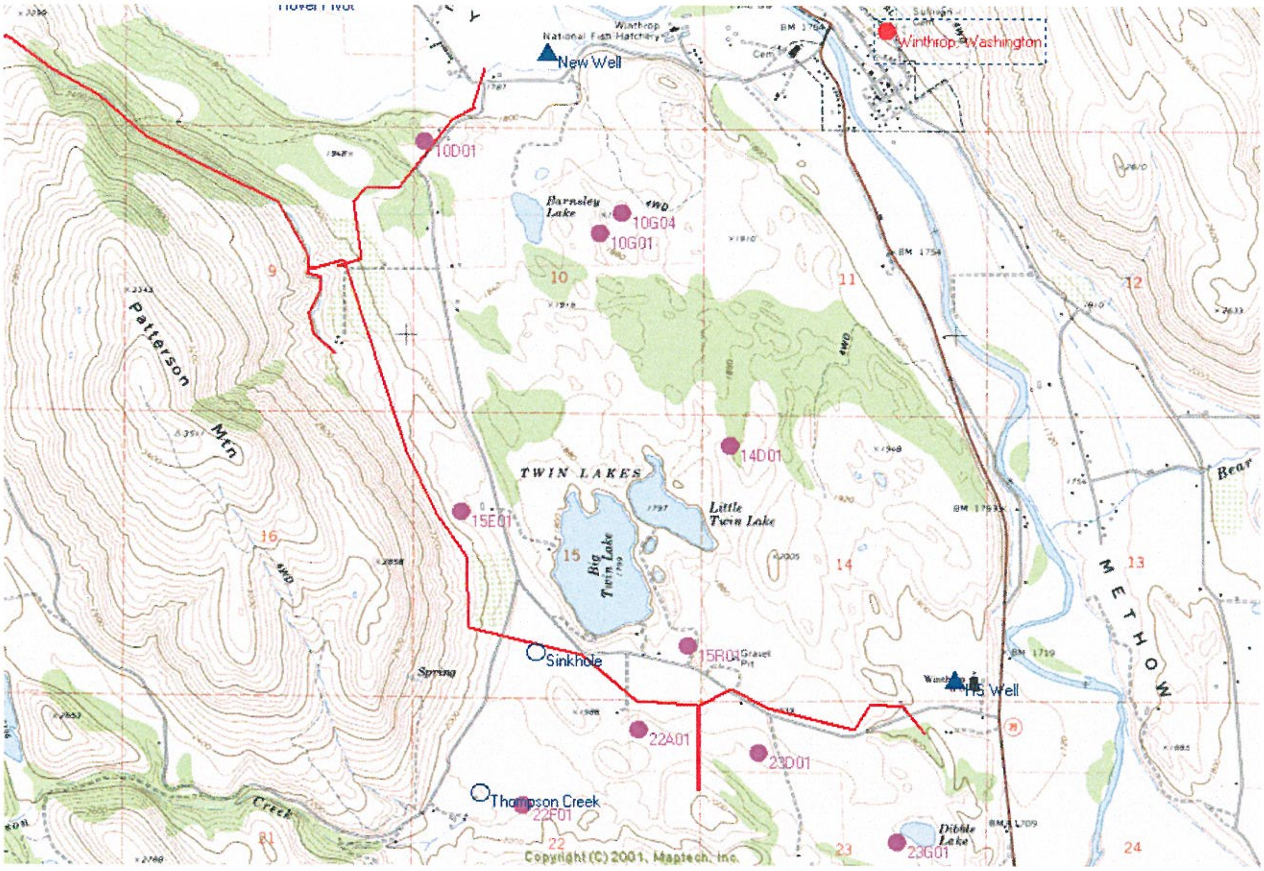

Figure 1. Location map of Twin Lakes Aquifer and features referred to in report. Red lines are the Wolf Creek Reclamation District's Delivery System.

The water levels in the Aquifer dramatically increased in 1922, following the completion of the Wolf Creek Reclamation District's (WCRD) main irrigation canal. This canal, like virtually all un-lined irrigation canals, leaked a substantial amount of water during the irrigation season. Since that time, the Aquifer levels have stayed high, but varied due to variation of loses from the canal system and precipitation recharge.

In August of 2001, the Wolf Creek Reclamation District converted approximately 13,480 feet of the canal to a pressurized pipe. Approximately 12,000 feet of this piped canal provided seepage to the Aquifer. This conservation action has prevented several hundred acre feet of water from being introduced into the Aquifer on an annual basis.

From 1999 to the present, the National Marine Fisheries Service has restricted WCRD's diversions from Wolf Creek. These restrictions prevents the WCRD from diverting water from Wolf Creek when flow depths at lower Wolf Creek (near its confluence with the Methow River) drops below 8 inches in depth. This restrictions, together with low flows from Wolf Creek limited WCRD's diversions from 1998 to 2002. We believe that these lower diversions and resulting applications of water to the WCRD further restricted return flows from the irrigation district from recharging the Aquifer.

Lastly, low precipitation from 1999 to 2002 limited natural recharge of the aquifer. These three factors (canal lining, low WCRD diversions, and low precipitation) resulted in water levels in the Aquifer declining by as much as 11 feet from 1998 to 2002. The lowering of the Aquifer also caused water levels in Twin Lakes to drop and another lake in the area (Barnseley Lake) to disappear.

This decline in Aquifer levels has been nearly catastrophic on several levels:

- Loss of property values of 30% for land owners adjacent to the lakes,
- Several wells in the area have gone dry and had to be deepened. Some wells experienced a severe degradation of water quality. Still other wells have/or will soon be rendered useless because there is no additional water that can be developed even if they are deepened,
- Resident fish in Little Twin Lake have been killed as the lake levels dropped and the remaining water became anaerobic (little to no dissolved oxygen) with elevated temperatures,
- Barnsley Lake lost its entire population of painted methow turtles, and
- The local economy is impacted due to the loss of a popular recreational fishery and the fact that the Big Twin Campground has lost business due to the loss of the fishery and scenic beauty of the Lakes.

To combat these problems, residents of the Winthrop area formed the Twin Lakes Aquifer Coalition (TLAC). The TLAC procured funds from the Washington Department of Ecology to contract with a consultant who will assist the TLAC with identifying and engineering an alternative(s) to rectify the problems.

The TLAC selected IRZ Consultants, LLC (IRZ) in November 2002 to develop the potential solutions and costs. IRZ evaluated the available information and filled in some of the data gaps. On December 16, 2002, IRZ met with the TLAC, WDOE, and several other stakeholders in Twisp, Washington to discuss the potential alternatives. As a result of that meeting, additional alternatives were developed and explored.

This is a final interim report. We intend for this report to be roughly the equivalent of a Feasibility Study. We have evaluated the problem and developed potential solutions and costs for the preferred solutions. However, because of the extreme time constraints, not all of the field work has been completed. For example, several of the potential alternatives result in water being added to the Aquifer through the Barnsley

Lake bottom. However, due to time considerations, we have not completed the field work to ensure that this is a good means of introducing water to the Aquifer. There are other limitations as well (the limitations are discussed in this report).

As a result, following the review of this report by the legislature, IRZ will continue to evaluate the alternatives with the consideration of comments by the legislature and stakeholders. IRZ will complete the necessary field and engineering work by June of 2003, such that construction contracts can be let (assuming that necessary funding of the selected alternative(s) can be developed).

In the sections that follow, we discuss the geology of the Aquifer, the history of the Aquifer in response to induced changes, the magnitude of the water sources to the Aquifer and problems, potential solutions, and the potential costs of the preferred solutions.

2. Geology of the Twin Lakes Aquifer

The size and boundaries of the Twin Lakes Aquifer can be determined fairly precisely in most of its extent. The Twin Lakes Aquifer consists of hummocky glacial deposits (silts, sands, and gravels- with occasional cobbles and boulders) that overly the sediments of the Methow River floodplain. The Aquifer is bounded to the east by the Methow River, to the west by bedrock of Patterson Mountain and other bedrock promontories. The Aquifer pinches out to the south as the bedrock promontories and the Methow River intersect (Figure 1).

The extent of the aquifer to the north is less well known. A reasonable estimate is that the aquifer extends north of Barnsely Lake to near the Winthrop National Fish Hatchery. This means that the aquifer is approximately 4.6 square miles in size.

These hummocky glacial sediments are chaotic in nature. A well that produces a great amount of water may be found near wells that produce much less water. An example of a geologic cross section developed by Glen Benzona (a local geologist and well driller and is part of the IRZ team) is seen in Figure 2.

Figure 2 was developed from wells near Twin Lakes. The cross section shows an overlying aquifer (Twin Lakes Aquifer) that is seen in the vicinity of Twin Lakes and Barnsely Lake. A second underlying aquifer, which is referred to as the Methow River Aquifer is considered to be an old channel of the Methow River. This aquifer is fairly narrow in extent, and is only found in certain areas in the vicinity of Twin Lakes. As a result, not all wells that are developed in the Twin Lakes Aquifer can be deepened to tap the Methow River Aquifer.

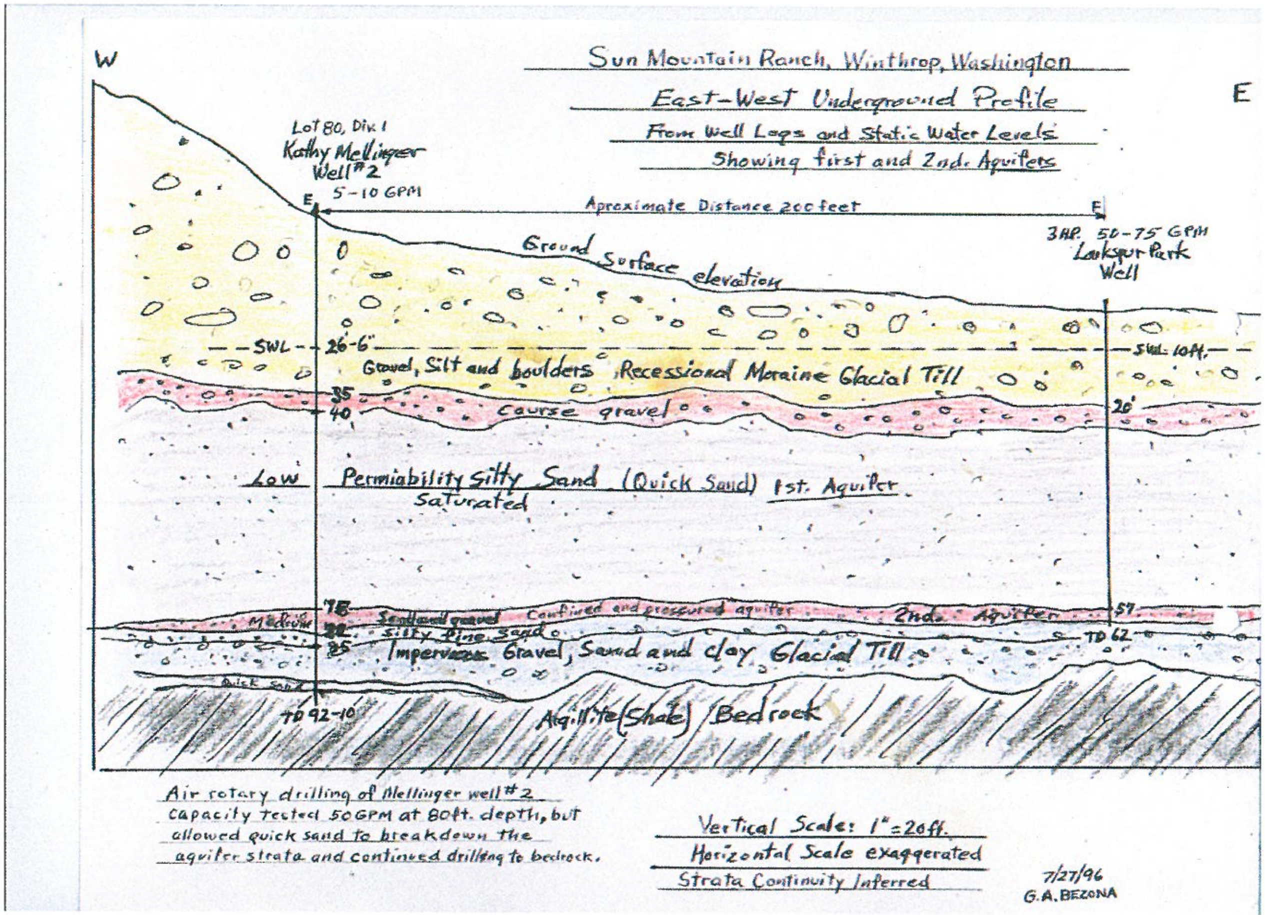

Figure 2. Geologic cross section showing complexity in geology near Twin Lakes. Source: Glen Bezona

3. Hydrogeology of the Twin Lakes Aquifer

Because the Twin Lakes Aquifer properties vary so much from location to location, there is not a lot of unifying information that can be determined about its principal hydraulic properties; hydraulic conductivity and specific yield. The hydraulic conductivity is a measure of the amount of water that can be transmitted to a well or through a cross sectional area. The specific yield is a measure of how much water can be yielded through a unit decline in head. Because the Aquifer is so heterogeneous, properties determined at one well may not be representative at another location.

These properties are extremely important, but are not well known. For example, if the aquifer is filling due to recharge, it will also start to discharge more water to the Methow River. The hydraulic conductivity is a measure of how much water will be discharged as the aquifer is recharged. The hydraulic conductivity can be roughly estimated through material properties, no more precisely than one hundred fold (0.10 to 10 ft/day).

The specific yield is the principal measure of how much water will be needed to recharge the aquifer in a unit area. The specific yield can not be estimated more precisely than three fold (0.10 to 0.30).

The hydrology of the Twin Lakes Aquifer is important to determine how much water has been lost in the Aquifer since the pipeline was installed in 1999, how much water will be needed to restore the Aquifer levels, and the amount of water that will be required to maintain the levels that we wish to re-establish. As previously stated, the main water sources are natural precipitation and the return flows from the Wolf Creek Reclamation District. These factors are discussed below.

3.1 Precipitation Recharge

The recharge from precipitation to the Twin Lakes Aquifer is a function of the form and amount of the precipitation (rainfall or snow melt), drainage area topography, and the evapotranspiration (ET) in the area.

There is a long term weather station in Winthrop, Washington. The average precipitation at this station was 13.9 inches from 1959-2002. The standard deviation for this station is 3.0 inches (84% of the average annual precipitation would be from 10.9 to 16.9 inches), according to National Climate Data Center records. Figure 3 shows the annual precipitation data for Winthrop, Washington for 1959 to 2002.

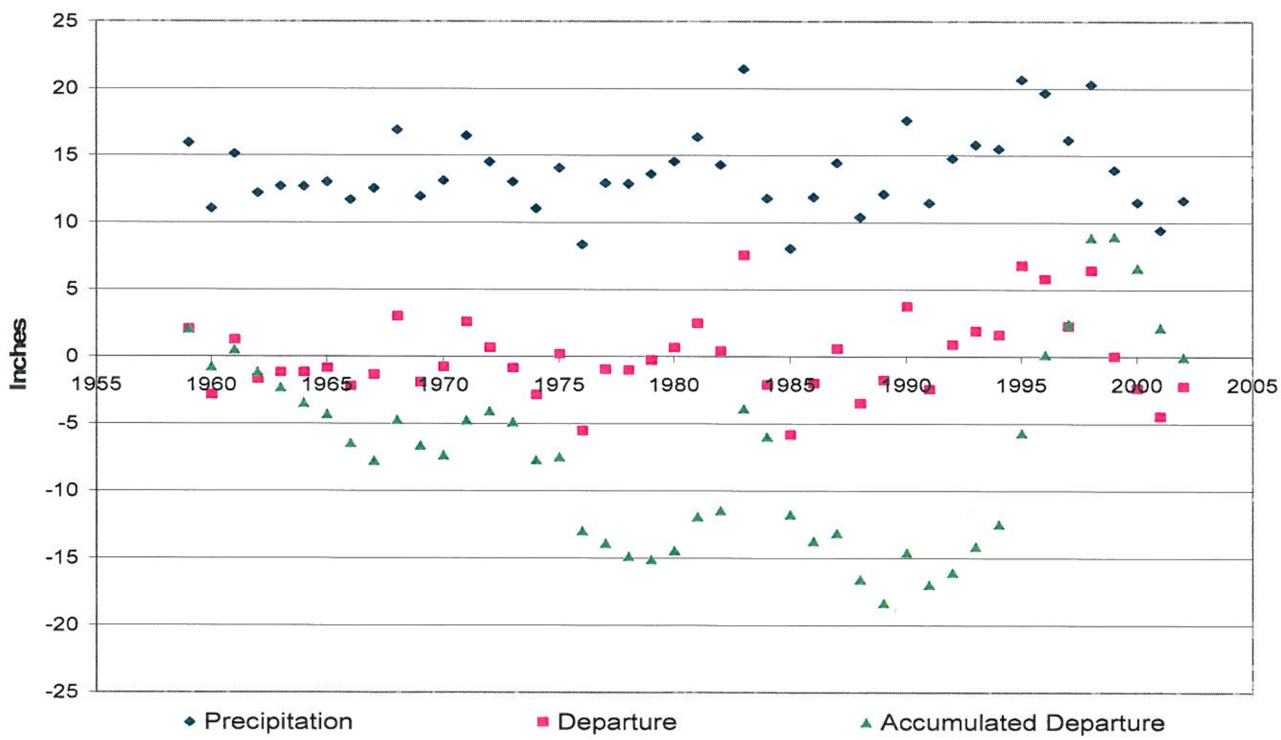

Figure 3. Precipitation data for Winthrop, Washington for 1959 to 2002.

The most important plot series on Figure 3, as an indicator of recharge to the Aquifer over time, is the accumulated departure trend (Accumulated Departure) as shown as the green triangles. This plot, by definition begins and ends at 0 inches and sums the Departure (purple square) series by year. As can be seen on Figure 3, the accumulated departure trend stays below zero (less annual precipitation than average) until 1996. It then trends from strongly negative in 1989 to strongly positive in 1998. In that 9 year period there was an accumulation of nearly 30 inches of excess precipitation (-20 to +10).

From 1998 to 2002, this trend reverses and becomes strongly negative with nearly 10 inches of deficit precipitation during that period. This means, if the Aquifer level is strongly dependent on precipitation for recharge, that aquifer levels might be expected to rise from 1989 to 1998 and fall from 1998 to 2002.

Figure 3, indicates that precipitation trend discussed above, may be highly relevant. Even though it is impossible to determine groundwater levels over time from before about 1990, it is possible to determine the elevation of Big Twin Lakes (with some certainty to about 1934 and with less certainty to 1922). This may be done by using a lake level/lake area relationship developed during this study. This relationship is best for showing trends. Individual levels are subject to some error.

The elevation of Big Twin Lake is an excellent indicator of groundwater levels because the lake and the groundwater are connected. As can be seen in Figure 4, it appears that the elevation of Big Twin Lake rose from 1922 until 1946. From 1946 until 1990, the level of Big Twin Lake dropped approximately 11 feet. It then rose from 1990 until 1998 and dropped again from 1998 to 2002, following the precipitation trends in Figure 3 and discussed above.

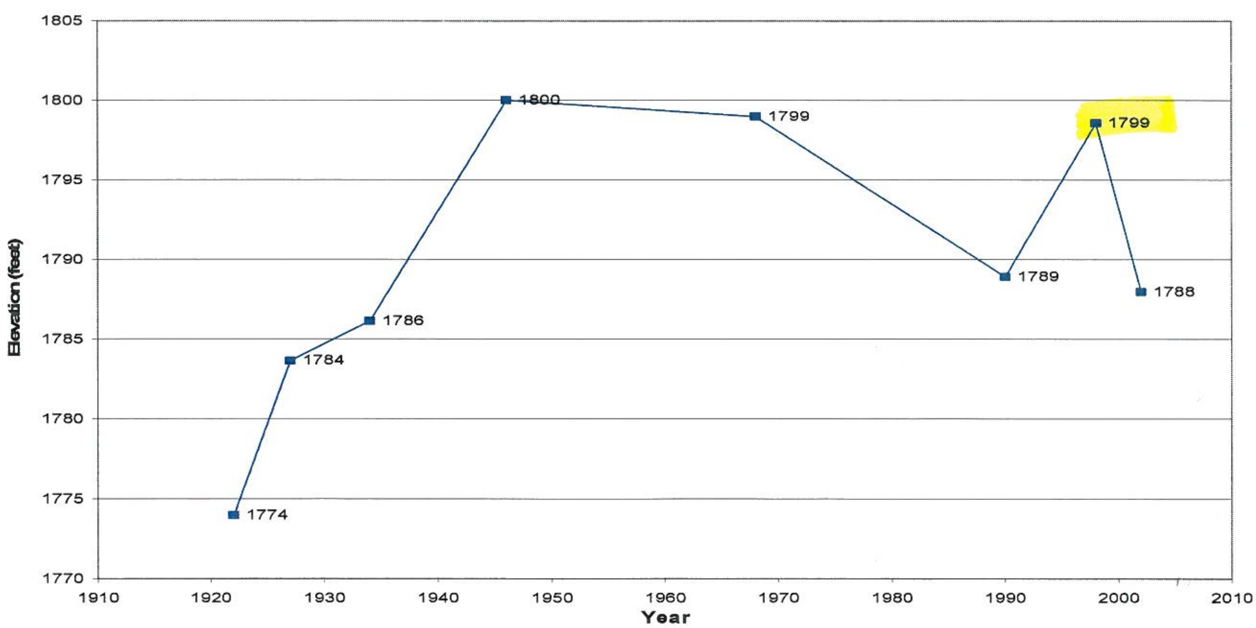

Figure 4. Big Twin Lake Historic Lake Level.

The Big Twin Lake level, is highly useful in determining the effects of precipitation. It can be bolstered by considering the long term groundwater measurements of wells that have been made in the area.

The USGS has been monitoring some of the wells in the Aquifer since 1980. Well monitoring has increased in intensity since 2000, due to concern expressed by residence of the area of their declining well-water levels.

Figure 5, shows the trend in those wells that have been monitored over a long period of time. As can be seen in Figure 5, the depth to groundwater was generally deeper when the wells were first monitored form 1980 to 1994. This period generally coincides with the deficit precipitation shown in Figure 3. However, as the wells have been measured more extensively from November 2000 until August 2001, the depth to groundwater has increased by several feet in these wells.

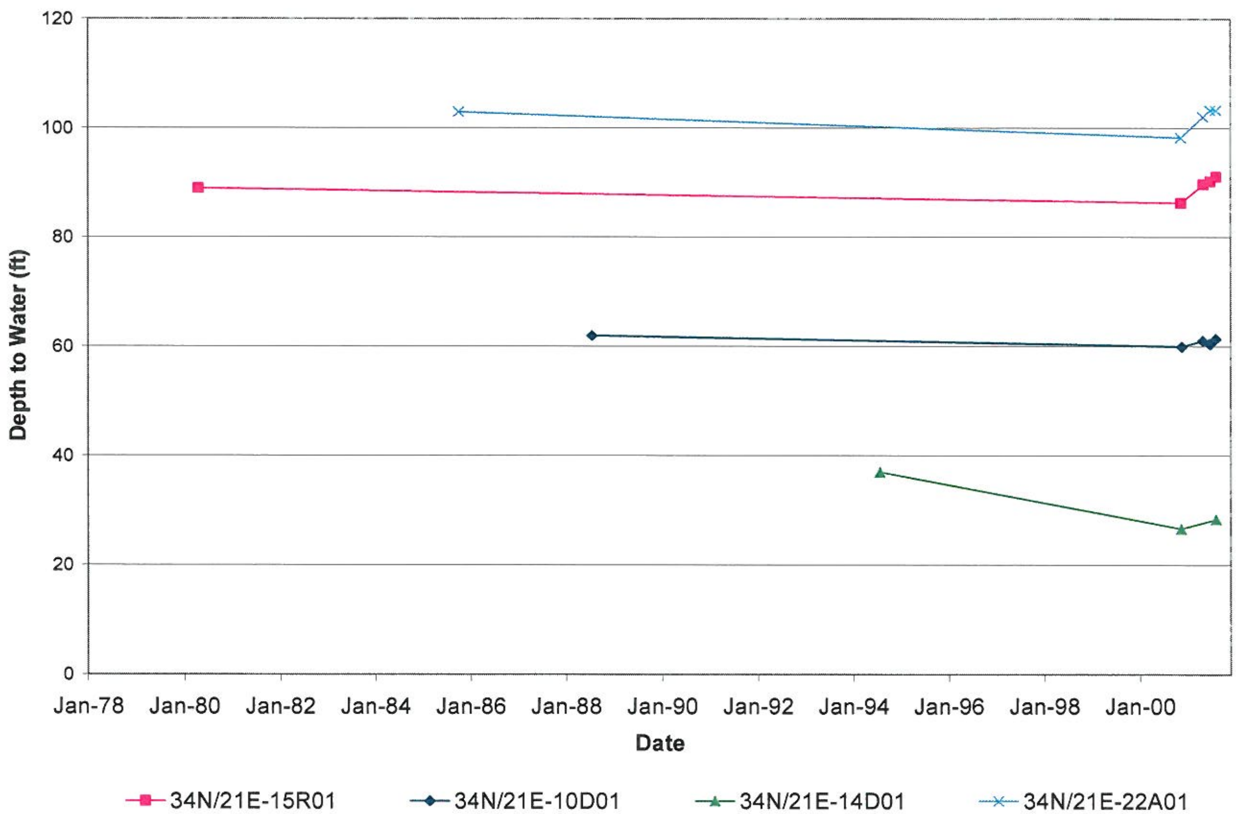

Figure 5. Twin Lake Aquifer Levels.

These groundwater measurements, as shown in Figure 5, help to support the trends shown in Figures 3 and 4. However, the well monitoring missed the greatest water levels in 1998 and is not indicative of the present water levels.

IRZ, in December 2002, located and measured several wells (with the assistance of members of the TLAC) that better illustrate this extreme drop in water levels. We found a well that is very close to Big Twin Lake and was drilled and measured in 1988 (presumed maximum groundwater levels). When we re-measured this well in December 2002, the water levels had dropped almost precisely 11 feet (the same trend shown in Figure 4).

If we assume that the aquifer is 4.6 miles in size, that the 11 foot drop in water levels is uniform across the aquifer, and that the specific yield of the aquifer is 0.1, this means that the aquifer has lost about 3,250 acre feet of water from 1998-2002.

We must add the loss in lake volume of Twin Lakes and Barnsley Lake to this Aquifer loss figure. The volume of water loss in the lakes is approximately 1,100 acre feet. This means that the total water lost in the Aquifer is approximately 4,350 acre ft. However, it could be nearly 3 times greater if the specific yield of the Aquifer is 0.3 rather than 0.1 assumed above.

The decrease in Aquifer levels from 1998 to 2002, with a deficit of 10 inches of precipitation is greater than the rise from 1990 to 1998, with an excess of 30 inches of precipitation. Clearly other factors, besides natural precipitation are responsible for the precipitous drop in the elevation of Big Twin Lakes and the associated groundwater levels in the Aquifer. These factors are discussed below.

3.2 Wolf Creek Reclamation District's Water Management Activities

It is becoming increasingly recognized that irrigation districts have a great deal of influence in modifying the natural hydrology of a watershed. Certainly, irrigation diversions diminish streamflows, particularly immediately downstream of the diversion. However, it is also increasingly clear that the irrigation return flow from a district may supply a substantial amount of water back to a river, supplementing stream flows at times and locations that may prove advantageous for fisheries and other purposes. This trend can be best locally seen in the Columbia Basin Irrigation Project and surroundings, where irrigation has **increased** groundwater recharge by approximately 3,700 cubic feet per second (cfs). These same sources of irrigation return flow (canal leakage and return flows from application of irrigation water to fields) occurs in the Wolf Creek Reclamation District.

As previously stated, the Wolf Creek Reclamation District started diverting water from Wolf Creek and applying that water in and near the Aquifer area in 1922. This change in the hydrology of the Aquifer is strongly believed to have increased the water levels in Big Twin Lakes and the surrounding Aquifer by about 25 feet from 1922 to 1946 (Figure 3).

In 1999, the WCRD completed a construction project to pipe the water that use to flow in an un-lined canal. It is not certain how much water efficiency was gained (or how much recharge to the Aquifer was lost) because WCRD did not and does not measure water applications at various points in the delivery system. However, using seepage studies performed on the Chewuch and Fulton Canals by the USGS and IRZ, it is extremely conservative to assume that **at least 25% of the 1,650 acre feet** that was typical diverted through the main canal, or 400 acre feet/year would be gained through efficiency (or lost to the Aquifer) through piping in the main canal.

The WCRD diverted about 3,000 acre feet/year (in accordance with their water rights) in a typical irrigation year before 1999 (WCRD records 1986-2002). This can be seen in Figure 6, a plot of WCRD diversion. Diversions in 1995 were low because another watershed that provides WCRD with irrigation water (Little Wolf Creek) had an unusually high runoff. Applications of water in 1995 were typical of other years- it just did not result from Wolf Creek diversions.

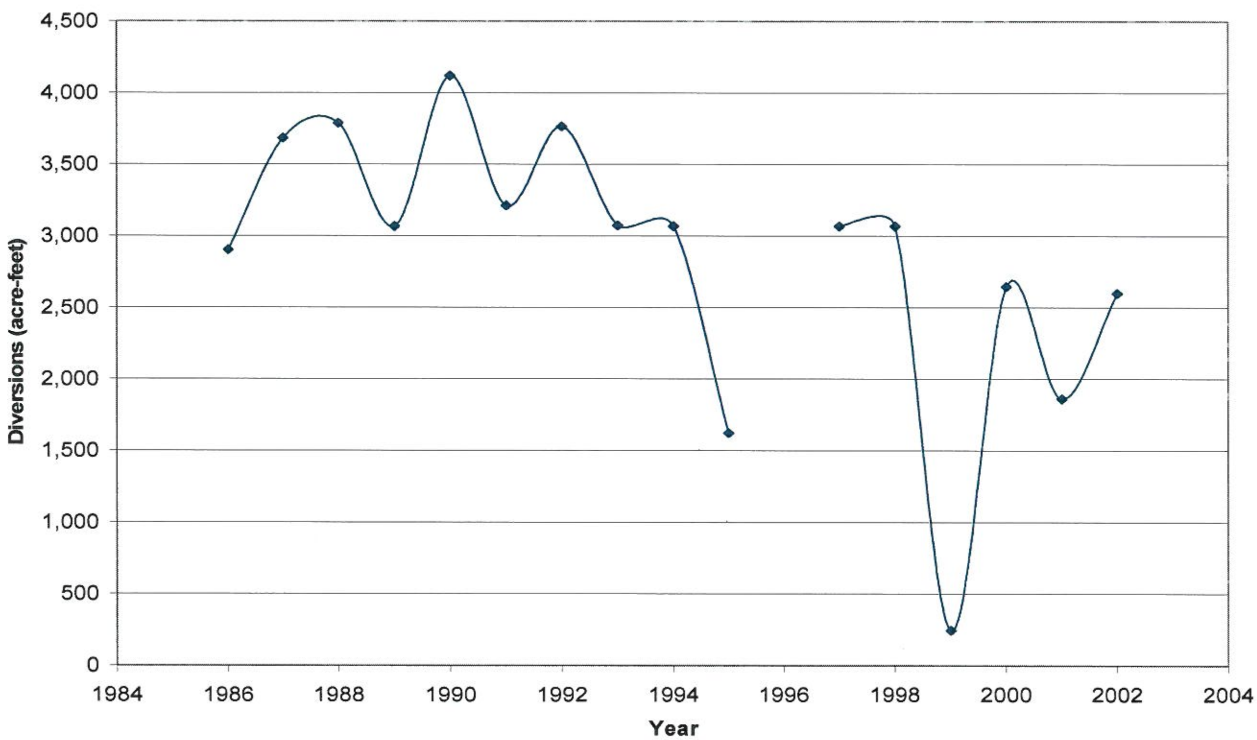

Figure 6. Wolf Creek Reclamation District Diversion from 1986 to 2002.

These diversions were fairly constant (before 1999) even though the precipitation in the Methow River basin may not have approached the average. This can be seen in Figure 7 which is a plot of WCRD diversions verses deviations in precipitation. Figure 7 indicates that the WCRD diversions remained fairly constant even though precipitation may have been greater than normal, or more significantly, less than normal. This factor is important because it strongly suggests that the Aquifer received a steady, constant source of irrigation return flows before 1999. Those years that plot significantly below 3,000 acre feet of diversions included 1995 (discussed above) and 1999-2002.

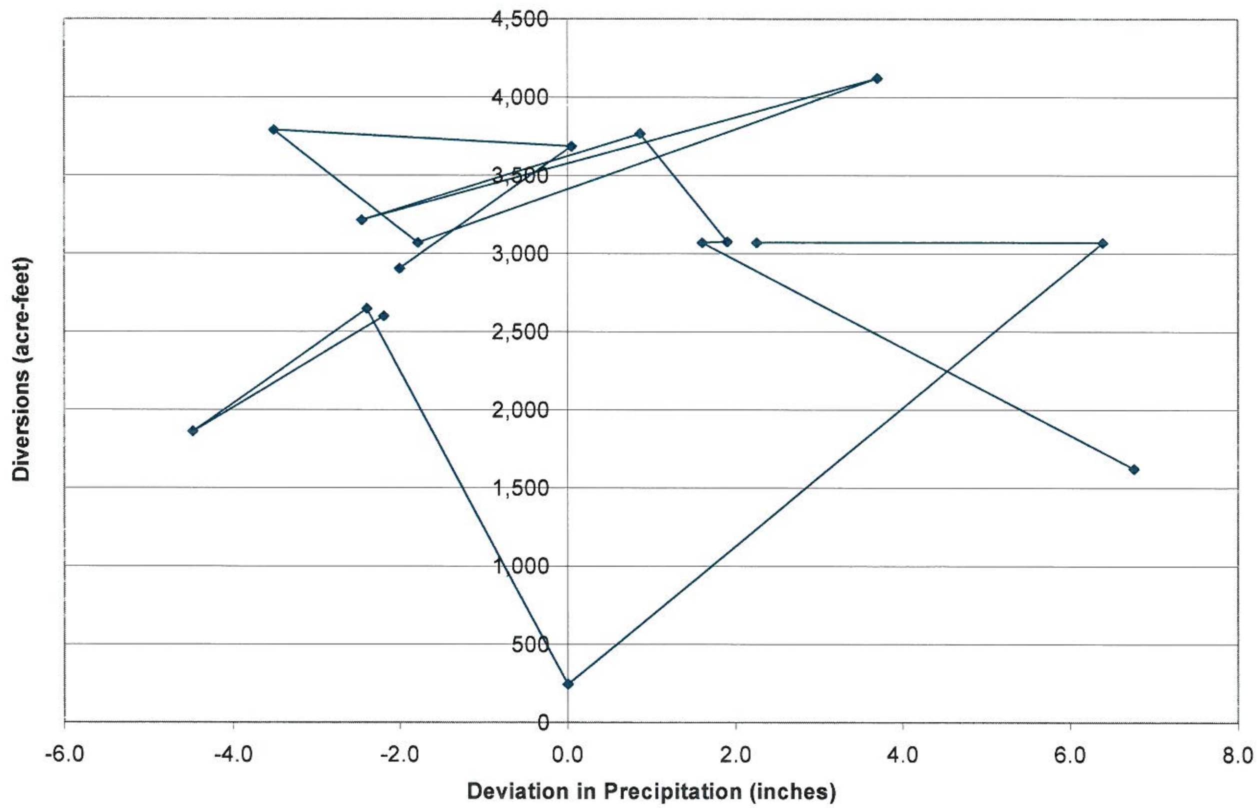

Figure 7. Wolf Creek Reclamation District Diversion verses Deviations in Precipitation.

It is difficult to estimate the amount of return flows from application of irrigation water because of imperfect records and because not all of the irrigated field's return flows would recharge the Aquifer. For example, the largest single irrigated holding (Haubs Trust) has about 450 acre feet of water rights. However, their irrigation circle probably does not contribute return flows to the Aquifer.

In the years before 1999, the maximum amount of return flows from applied irrigation water to fields could be assumed to be about 420 acre feet (85% irrigation efficiency for sprinkler irrigation from 800 irrigated acres at a duty of 3.5 ft/acre/year). However, based on topography, it appears that about half of the irrigated acres could recharge the Aquifer (about 210 acre feet/ year of recharge before 1999). Since 1999 and the marked reductions in diversions from Wolf Creek (and applied water) it is likely that return flows from these fields has been largely eliminated.

These two factors (canal lining and lower application rates to the irrigated fields) combined means that the changes in the WCRD management activities have diminished return flow to the aquifer about 600 acre feet per year from the period of 1999-2002 or about 2,400 acre feet since the management changes began in 1999. This is at least **55%** of the total water lost in the Aquifer. The other **45%** of water lost would be presumably due to lower precipitation from 1998 to 2002.

3.3 Hydrology Conclusions

The hydrologic history is important because the Aquifer water lost, and by what source, is our principal way to estimate the severity and the scope of the problem. The conclusions from the above analysis are that approximately 4,500 acre feet of water has been lost in the Aquifer from 1999 to 2002. At least 55% of that total (or 2,400 acre feet) appears to be due to changes in management practices of the Wolf Creek Reclamation District. This 4,500 acre-feet is the minimum amount of water that will be necessary to restore the Aquifer to the desired 1998 levels because:

- The specific yield figure of 0.1, which is probably the best estimate of the voided area in the aquifer, could be considerably higher and
- As water is added to the Aquifer and groundwater elevations increase, the groundwater discharge of the aquifer will increase.

Therefore for design considerations, it should be assumed that about 9,000-10,000 acre feet of additional introduced water will be required to restore aquifer levels. Greater than average precipitation may help to restore the Aquifer levels but should not be relied on. This means that if we can add an additional 2,000 acre feet of water per year for 5 years (**above the current rate of recharge**), that the Aquifer should be filled to the desired 1998 levels. Additionally, 600 acre feet of water will have to be added per year after that to offset the management changes discussed above.

4. Brainstorming Additional Water for the Twin Lakes Aquifer

There are numerous possibilities for adding water to the Twin Lakes Aquifer. Broadly grouped, they consist of adding additional water to the aquifer (through gravity or pumping) or finding water through additional efficiencies and adding that save water to the aquifer. Almost every measure evaluated will require additional water right(s). After the measures are discussed they are evaluated through a spread sheet matrix. Finally, the costs of the most promising measures were estimated and the most appropriate selection(s) are recommended. The measures identified through the input of participants are discussed below.

4.1 Additional Water-Gravity Sources

The most promising aspect of these water sources is that they can add water to the Aquifer without having to pay an annual pumping cost. There are several potential gravity sources, discussed below.

4.1.1 Increase Diversions Flows from Wolf Creek

The Wolf Creek basin is a highly useful source of additional water. The water quality is good and the water is available (with a new water right) for about 2-3 months per year, based on USGS and USFS stream gaging records and US Fish and Wildlife fish passage criteria. About 4 cfs of additional water could be diverted for these 2-3 months (480-710 acre feet per year) with some improvements to the canal and piping system and with the addition of a new fish screen at the diversion. Water could be added to the Aquifer at Barnsely Lake.

4.1.2 Increase Diversion Time from Wolf Creek

There is a possibility that the diversion season could be increased in some years by diverting water earlier in the season. There would be very little additional costs for this measure, with the exception of the water right. Only a small, unknown amount of water could be diverted in most years. Water could be added to the Aquifer at Barnsely Lake.

4.1.3 Thompson Creek Diversions

Some water is available from Thompson Creek, which is located near Patterson Lake (Figure 1). This water could be diverted to a sink hole near Big Twin Lake and would presumably be discharged to the lake. Raising the lake will recharge the groundwater. We believe that 1-2 cfs (500-1,000 acre feet annually) could be added to the lake in nine months of operations in a year. A disadvantage to this measure is that water added to Twin Lakes is not as desirable as water added to the Barnsley Lake area. The water quality and quantity of this source is not known and could impact lake water quality. Primary water quality concerns are elevated temperatures in the summer and the possibility that not all pathogens may be filtered during the short, rapid groundwater path between the sinkhole and Big Twin Lake.

4.1.4 New Main Canal

The pipe line that was installed could be replaced by a new canal. Capital costs of this measure would be high. WCRD would lose the water they gained through the pipe efficiency. There is no control as to the time or location that water could be added to the aquifer.

4.1.5 Additional Water Through Pumping

Like the gravity measures, there are several sources of water that can be added to the Aquifer from pumped sources. In many cases, the capital costs of the measures are attractive, but the monthly power costs are much greater than the gravity measures.

4.1.6 High School Well Offset

The Winthrop High School (Methow School District) receives about 160 acre feet of water delivered through the WCRD system. Under this measure, the water that would normally be delivered to the High School would be diverted to Barnsley Lake. The high school would then pump groundwater for their irrigation purposes. The pumping costs for the High School to irrigate would be the only additional costs (assuming that no additional water right would be required). Exactly 160 acre-feet of water would be available with this measure. Potentially, the increased gradient caused by the pumping could increase groundwater discharge so not all 160 acre feet would be seen as a benefit.

4.1.7 High School Well Active Pumping Alternative

As discussed above, the Winthrop High School (Methow School District) can satisfy their irrigation requirements through their well. However, their well is capable of delivering additional water to Twin Lakes, by back pumping through the WCRD pipeline outside of the irrigation season. The well is capable of producing about 600 gpm, based on its size and the horsepower of the pump. Like the above measure, the water that would normally be delivered to the High School for irrigation would be diverted to Barnsley Lake. The pumping costs for the High School to irrigate, the additional pumping of the approximately 300 acre feet of water, plus some additional piping would be the only additional costs. This measure will require an additional water right.

4.1.8 Haubs Brothers Lower Pivot Water Rights Offset

This measure can only be used as a temporary water source according to the wishes of the owners of the water rights. The measure consists of paying the pumping costs to irrigate the Haub Brothers Lower pivot using a new well that has been drilled as a supplementary water source (Figure 1). This offset water could be temporarily transferred to the TLAC. New water rights would have to be procured to allow for the increased pumping from the supplementary well. Water saved from Patterson Lake and/or the WCRD collection facility would be discharged to Barnsley Lake. Up to 500 acre feet per year for five years could be generated under this measure.

This measure would not be acceptable for a permanent water supply, but could be used to add the large amount of water that is initially needed to restore water levels.

4.1.9 Methow River Water Right

This measure consists of developing a new water right from the Methow River when there is a surplus of flow. We estimate that on average, water could be diverted from this source for as much as 3 months a year. Water would be collected in a shallow interceptor well located near the Fish Hatchery (Figure 1) that would be in hydraulic connection with the river. A groundwater interceptor well would preclude such expensive requirements such as a fish screen. The water discharged from the well would be piped to Barnsley and Twin Lakes for recharge to the Aquifer. Under this measure, we anticipate a system capable of adding 1,000 acre feet per year during three months of pumping to these lakes.

4.1.10 Methow Aquifer Groundwater Right

This measure consists of developing a new water right from the Methow Aquifer. This aquifer is capable of producing as much as 1,500 gpm with a properly designed well for about nine months a year (or about 1,800 acre feet). This well would be drilled near Barnsley of Twin Lakes to reduce piping costs as much as possible. Possible impacts could include interference with existing wells and possible impacts of pumping from a deeper aquifer and adding an excess amount of water to a shallower aquifer.

4.1.11 Less Water Consumed by WCRD or Lost in the Twin Lakes Aquifer

These measures assume that there are potential efficiencies that can be realized in the operation of the WCRD. The water saved, could in theory, be added to the Aquifer. In virtually all of these measures, water measurements before and after the action would be needed to evaluate the magnitude of the action. For instance, if a portion of a ditch was lined, measurements would be needed to access the impact. An additional problem is that potential efficiencies by WCRD would not necessarily result in water for the Aquifer (an agreement would have to be made regarding funding sources and who would realize the efficiency gains).

Other potential measures would be to decrease the groundwater discharge by lining Twin Lakes (this option was quickly excluded) or by decreasing groundwater pumping in the Aquifer. These measures are discussed below.

4.1.11.1 Efficiency Gains in WCRD

This measure consist of lining some portions of the WCRD that are presently unlined including:

- Patterson Lake to WCRD collection box. Savings of 80 acre feet per year.
- WCRD collection box to Haub Brothers lower pivot collection box. Savings unknown.
- The unlined portions of the Wolf Creek-Patterson Lake canal. Savings unknown.

As discussed above, the water savings and availability of these measures are unknown (presumably small) and who would gain the savings is undetermined. In addition, some of the waste water from these areas may already recharge the Aquifer, so the net improvements are unknown.

4.1.11.2 Water Rights Transfers

It is possible that unused or underused water rights could be permanently or temporarily transferred to the TLAC for recharge of the Aquifer. Permanent transfers are less desirable from the effected communities perspective because the water rights and much of the value of the property could be lost with a permanent transfer. The amount of water that could be gained from transfers is unknown. However, temporary transfers appear to have some community acceptance and should not cost much to implement.

4.1.11.3 Irrigation Scheduling and Water Metering

These two measures could/should go together. In general, it is possible to achieve considerable savings of water through irrigation scheduling. Many clients have achieved water savings of 10% or more with a scheduling service (Fred Ziarai, personal communication, December 2002). Costs for scheduling are generally moderate, but would be hard to implement in an irrigation district with so few water measurements (therefore metering is a useful consideration) and so many small irrigators. In addition, it is uncertain who would realize the efficiency gains.

4.1.11.4 Line Twin Lakes

It is possible to Line Twin Lakes using a sealant such as bentonite. This would result in less water being lost through the lake bottom and would result in higher lake levels. This measure was quickly excluded because it does not restore aquifer levels.

4.1.11.5 Decrease Pumping in the Aquifer

This measure would increase Aquifer levels because less water would be depleted from pumping. However, most of the water that is pumped is not consumptively used (it returns through the septic system). Therefore, this measure is a good idea, but will not result in much of an improvement in Aquifer levels.

5. Evaluation of Measures

The measures discussed above were evaluated with a spreadsheet that allowed measures to be weighed using several factors. Based on our December 16, 2002 meeting, some of the evaluation criteria were given additional weight. Measures that received the higher scores were evaluated in more detail and feasibility level costs for those measures were developed. Costs for certain measures that made intrinsic sense were also developed. However, no measure that received a low score and had a low intrinsic value were given further consideration.

5.1 Evaluation Criteria

The evaluation criteria are identified here. Each criterion was quantified by a factor representing the magnitude of its impact. The greater the factor, the greater the impact. Table 1 summarizes these factors.

Table 1. Evaluation Criteria Factors.

Criterion	Factor	Impact
Capital Costs	0 to 10	Negative
Annual Costs	0 to 10	Negative
Quantity of Water	0 to 20	Positive
Acceptance by Effected Community	0 to 20	Positive
Acceptance by Regulatory Agencies	0 to 20	Positive
Place of Application	0 to 10	Positive

The capital costs factor represents an initial estimated order of magnitude. Higher annual costs are generally associated with alternatives that have pumping costs. If the acceptance by regulatory agencies was too low, the alternative was excluded from further analysis. The place of application factor was ranked with the most advantageous location to apply water (near Barnsley lake) receiving a 10 and the lesser locations to apply water (down gradient of Twin Lakes) receiving a low score.

The capital and annual costs are negative factors (subtracted from the score) while all the other factors are positive (added to the score). A perfect score with this matrix is 70 points (all positive scores and no negative scores). Table 2 shows the matrix score for the measures.

Table 2. Evaluation Matrix for Measures.

	Capital 0-10	Annual 0-10	Quant. 0-20	Accept. 0-20	Reg. 0-20	Place 0-10	Score
New Water							
Gravity							
Increase Wolf Creek Diversions (Discharge)	10	3	20	15	10	10	**42**
Increase Wolf Creek Diversions (Time)	2	3	3	10	10	10	**28**
Thompson Creek diversions	5	2	20	20	10	3	**46**
New main canal	10	5	20	3	3	5	**16**
Pumped							
High School offset	3	7	10	20	10	10	**40**
High School active pumping	5	10	15	10	10	7	**27**
Bud Hover offset	4	5	20	5	10	10	**36**
Methow River Right	10	10	20	20	20	10	**50**
Methow Aquifer Source	7	10	10	10	10	10	**23**
Less Consumed by WCRD or Lost in Twin Lakes Aquifer							
Efficiency gains in WCRD							
Line Patterson Lake-WCRD Ditch	5	3	5	10	10	10	**27**
Line Bud Hover Diversion Ditch	5	3	3	10	10	10	**25**
Line other areas in Wolf Creek diversion	7	5	8	10	10	10	**26**
Water rights transfers to TLAC							
Permanent	2	1	10	5	10	10	**32**
Temporary	2	1	10	15	10	10	**42**
Irrigation scheduling	3	3	3	15	10	10	**32**
Water metering	3	5	3	5	10	10	**20**
Line Twin Lakes	5	2	1	3	5	3	**5**
Decrease pumping in Twin Lakes area	0	2	1	5	10	5	**19**

Capital = Capital cost of alternative
Annual = annual cost of maintenance and or pumping costs
Quant. = Quantity of water available for alternative
Accept. = Community acceptance from those impacted by alternative

Reg. = Regulatory Agencies acceptance of alternative
Place = Place that water may be applied in aquifer
Score = Numerical score for alternative based on criteria

5.2 Costing for the Best Measures

From Table 2, there are several measures that appear to be significantly better than the others, based on the matrix values discussed above. They include, ranked by score:

- Methow River Water Source – 50 points,
- Increase Wolf Creek Diversions (discharge) – 47 points,
- Thompson Creek Diversion – 46 points,
- Water Rights Temporary Transfers – 42 points,
- High School Well offset – 40 points, and
- Bud Hover offset – 40 points.

All other measures were ranked significantly below 40 points and were excluded from further analysis.

The above measures, particularly when considered as elements of the whole answer, provide for the required Aquifer levels. For example, the Thompson Creek measure is probably not capable of recharging the whole Aquifer. However, if this measure is combined with some temporary pumping measures that could add water to Barnsley Lake, it becomes a strong element of a highly cost-effective option.

In addition, all of the measures listed above are readily achievable and provide flexibility for the future. As a result, almost any of the measures could be easily supported if a weakness was found in the preferred measures. All of the measures require some water rights transfer work and will require at least some metering of flows to implement. Preliminary costs for the above measures are listed below.

Measure 1a: Methow River Water Source: Shallow Well with Pipeline to Big Twin Lake with Branch to Barnsley Lake

Well	Construction of well	$ 20,000
	Pump (2,500 gpm @ 165 feet)	$ 10,000
	Motor (125 hp)	$ 10,000
	Utility Power	$ 6,000
	Electrical Control Equipment	$ 6,000
	Pump House	$ 8,000
	Sub-Total:	**$ 60,000**
Pipeline	Pipe	$ 77,000
	Miscellaneous	$ 10,000
	Installation	$ 53,000
	Sub-Total:	**$140,000**
Engineering, Legal, Construction Mgmt.		$ 20,000
Contingency and Sales Tax		$ 50,000
	TOTAL:	**$270,000**
Total Estimate Annual Costs	:	**$ 19,000**

Measure 1b: Methow River Water Source: Shallow Well with Pipeline to Barnsley Lake

Well	Construction of well		$ 20,000
	Pump (2,500 gpm @ 85 feet)		$ 6,000
	Motor (60 hp)		$ 6,000
	Utility Power		$ 6,000
	Electrical Control Equipment		$ 4,000
	Pump House		$ 8,000
		Sub-Total:	**$ 50,000**
Pipeline	Pipe		$ 29,000
	Miscellaneous		$ 5,000
	Installation		$ 16,000
		Sub-Total:	**$ 50,000**
Engineering, Legal, Construction Mgmt.			$ 10,000
Contingency and Sales Tax			$ 30,000
		TOTAL:	**$130,000**
Total Estimate Annual Costs		**:**	**$ 14,000**

As listed above, this measure has capital costs of $130,000 to $270,000 and would have an estimated annual cost from $14,000 to $19,000. The differences in the prices reflect two points of application with the first measure and only one in the second. The primary criteria for selection between these two alternatives would be if Barnsley Lake is capable of recharging all of the available water, which is somewhat doubtful based on our original sampling of the lake bottom sediments.

Measure 2. Increase Wolf Creek Diversions

Increased Diversions 4 cfs			
	Fish Screen		$ 60,000
	Pipeline retrofit		$140,000
		Sub-Total:	**$200,000**
Engineering, Legal, Construction Mgmt.		:	$ 20,000
Contingency and Sales Tax		:	$ 40,000
		TOTAL:	**$260,000**
Total Estimate Annual Costs		**:**	**$ 4,000**

Measure 3. Thompson Creek Diversion

Diversion			**$ 20,000**
	Concrete Structure		
	Trash Rake and Screens		
	Control Gate, Miscellaneous		
Pipeline	Pipe		$ 10,000
	Installation		$ 10,000
		Sub-Total:	**$ 40,000**
Engineering, Legal, Construction Mgmt.		:	$ 10,000
Contingency and Sales Tax		:	$ 10,000
		TOTAL:	**$ 60,000**
Total Estimate Annual Costs		**:**	**$ 2,000**

Measure 4. Water Rights Temporary Transfers

We assume that the manpower to address the water rights transfers in this measure (which could be extensive) and several of the other measures would take 1 man year (or $100,000 for labor and other costs). Water metering would have to be done (at least at the Barnsley Lake recharge area) to ensure that the transferred water was added to the Aquifer.

Measure 5. High School Well Offset

Assuming that the High School well can produce 600 gpm, that the pumping lift is around 80 feet, and that the required discharge pressure is approximately 80 psi (requiring a 50 horsepower pump); the electrical demand will be 42 kW and the energy usage per acre-foot of water pumped will be 383 kWh/ac-ft.

To pump the total water right of 140 acre-feet would require a total energy usage of 42,300 kWh. At an energy cost of $0.035 per kWh, the total energy cost, excluding demand charges, would be **$1,700**.

Measure 6. Huab Brothers lower pivot Offset

Assuming that Bud Hover's new well can produce 1,200 gpm, that the pumping lift is around 60 feet, and that the required discharge pressure is approximately 80 psi (requiring a 100 horsepower pump); the electrical demand will be 76 kW and the energy usage per acre-foot of water pumped will be 343 kWh/ac-ft.

To pump the total water right of 490 acre-feet would require a total energy usage of 168,300 kWh. At an energy cost of $0.035 per kWh, the total energy cost, excluding demand charges, would be **$5,900**.

5.3 Ranking of Options

The measures that were evaluated provide some excellent ways to restore the water level in the Aquifer and all of the measures are of a reasonable cost. However a few measures, considered together provide the best means of fulfilling the main criteria while still providing flexibility for the future when not as much water will be required.

5.3.1 Preferred Option: Thompson Creek Diversion with Temporary Water Rights Transfers.

The Thompson Creek diversion, with a capital cost of $60,000 and an annual cost of $2,000 is the most cost effective strategy, particularly because of the great amount of water that can be added (500-1,000 acre feet) at such a low cost. This is also a great option for adding the maintenance water to the aquifer. The main drawback will be if the drainage is not capable of producing as much water as we estimate. Therefore, this option will be tested in the next phase to see how much water is available.

5.3.2 Second Preferred Option: Wolf Creek Diversion with Temporary Water Rights Transfers

If the preferred option proves to provide too little water, the preferred alternative would be to increase the Wolf Creek diversions, because of its flexibility to add maintenance water in the future without annual pumping costs.

5.3.3 A Strong Third Option: Methow River Pumping with Temporary Water Rights Transfers

The Methow River water source is also an acceptable alternative but will always have a high pumping cost. As a result, it should be considered as a third, but satisfactory option, because it is not as desirable for future flexibility.

5.3.4 A Subordinate, but Highly Necessary Requirement: Temporary Water Rights Transfers

With these options providing a significant level of recharge and the means of maintaining water levels in the future, additional, temporary pumping alternatives are available to help provide the initially large amount of water that is needed.

The High School Well Offset appears to have the best combination of costs and acceptance. The Bud Hover Pivot should be included if the proper transfers can be arranged and agreements can be reached with the water rights owners. Temporary water rights transfers, from members of the WCRD should be completed, if the acceptable mechanisms and agreements should be reached.

6. Five Year Costs for the Preferred Option

The project cost for this preferred option (Thompson Creek Diversion and Temporary Water Rights Transfers) includes a total of $60,000 for the Thompson Creek Diversion and $10,000 to operate this diversion for five years. The well at the high school should be operated for five years at a cost of $8,500 and the water added to Barnsley Lake. Another water right (the Haub Brothers lower pivot) should be served by groundwater pumping for five years (if feasible) at a cost of $29,500.

A diversion system should be built at a cost of $15,000 to add water from the Barnsley Lake lateral to Barnsley Lake. Water metering requirements will add an additional $25,000 for the five year period for metering, recording of data, and reporting requirements. And finally, a series of temporary water transfers and new water rights should be completed for a total of $100,000. These measures result in a total project cost of **$248,000** for the five year period.

If the Thompson Creek measure proves to be unreliable (we don't know very much about the hydrology of this stream), the Thompson Creek diversion would be scrapped and the second preferred option, Increase the Diversion at Wolf Creek would be implemented. The project total for the five year period would be approximately **$443,000**.

The third option, pump water from the Methow Valley Aquifer, would have a project total for the five year period of approximately **$340,000** to **$505,000**. The lesser amount is if water could be introduced solely at Barnsley Lake.