APPENDIX G

Kootenai River Valley Agricultural Seepage Study Summary Report

Kootenai River Valley Agricultural Seepage Study Summary Report

Boundary County, Idaho

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US Army Corps of Engineers ®
Seattle District

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EXECUTIVE SUMMARY

The effects of six different Libby Dam operational scenarios on agricultural production and economic losses attributed to seepage[1] in the Kootenai Valley were estimated using a combination of field observations and data, computer modeling tools, and economic statistics. The methods used provide a regional evaluation of potential changes in groundwater conditions, crop yield, and production value for two years: a typical year as represented by simulation of the six operational scenarios for hydrologic conditions in 1964, and a more significant year as represented by simulation of the six operational scenarios for hydrologic conditions in 1961.

Estimates of dollar losses (in 2003 dollars) for different dam operations appear to include baseline losses on the order of $2,000,000. In all cases, impacts to hops produce the largest losses for a single crop. Annual crop losses are dominated by spring wheat, winter wheat, and barley.

In a typical year such as 1964, agricultural impacts for any given fish flow operation would be similar, regardless of the flood control operation of Libby Dam. In these years, total impacts due to high groundwater are estimated to be about 50% higher with fish flows than without. Estimated economic losses due to high groundwater in a typical year such as represented by 1964 range from $2,609,000 to $3,940,000, which include some level of baseline losses.

In a more significant year like 1961, where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impacts under any of the scenarios, and VARQ flood control operations are estimated to generate higher impacts than compared to Standard flood control operations. Fish flows are expected to add to impacts in more significant years, but additional losses are estimated at about 10% of total impacts, much less than the relative contribution of fish flows in more typical years. As happened in the VARQ flood control simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations may supersede fish flow considerations. Estimated economic losses due to high groundwater in a significant year such as represented by 1961 range from $4,714,000 to $5,860,000, which include some level of baseline losses.

1.0 STUDY PURPOSE

The purpose of the study is to identify and quantify the effects of high groundwater levels on agricultural in the Kootenai River Valley given different flow regimes generated by

[1] The term “seepage” refers to the physical transference of water; the high groundwater condition that results from this transference is sometimes referred to as “waterlogging.”

different flood control and fish operations at Libby Dam, which regulates Kootenai River flows. This project is a requirement of the 2000 US Fish and Wildlife Service Biological Opinion (reasonable and prudent alternative components 8.1.d and 8.3.c). The study results will inform the Upper Columbia Alternative Flood Control and Fish Operations Environmental Impact Statement (UCEIS) scheduled for release for public comment in mid-2005.

Agricultural interests and officials in Boundary County, Idaho have identified agricultural impacts resulting from seasonally high groundwater levels in agricultural areas along the Kootenai River. Affected parties have asserted that spring flow augmentation for endangered Kootenai River white sturgeon is responsible for keeping river levels high for periods long enough to produce areas of saturated soils in fields, thus affecting crop production and associated farming activities.

Concerns about the impact of high groundwater levels on agriculture in the Kootenai Valley date back to before Libby Dam and played prominently in “reclamation” activities in the early 1900s (Tolman 1923). A detailed 1987 Corps study on damageable property between Libby Dam and Kootenay Lake (Seattle District Records c/o Don Bisbee) describes agricultural damages that occurred during major flooding events prior to Libby Dam, as well as potential impacts on agriculture from seepage during the flood season. To date, construction of Libby Dam has largely eliminated major flooding, but high groundwater levels and the consequential impacts on crops continue to be an issue for local growers.

Spring flow augmentation for sturgeon commenced at Libby Dam in 1992 and heightened concerns by local agricultural interests about impacts of high groundwater levels. The 1995 Columbia River System Operation Review (SOR) Environmental Impact Statement (EIS) documented the effects of various alternative operations of federal dams in the Columbia River basin (including Libby), but did not address the potential impacts of high groundwater levels on Kootenai valley agriculture because the issue was not identified in scoping or public comments.

Since the 1995 SOR EIS, the Seattle District has attempted to better quantify the potential relationship between dam operations, high groundwater levels, and agricultural impacts in the Kootenai valley. Previous studies that address this phenomenon include Harp and Darden (2001) and HDR Engineering, Inc. (2001), and Corps (1998). Based on observations of recent conditions and impacts, these studies identified the issue of high groundwater-induced impacts on agricultural production and produced rough estimates of dollar losses due to lost or reduced agricultural production. Unlike the study at hand, these studies did not allow prediction of potential agricultural and economic impacts resulting from potential future conditions and various different Libby Dam operational scenarios.

2.0 BACKGROUND

2.1 Pre-Dam Conditions

Prior to construction of Libby Dam, spring runoff in the Kootenai River at Bonners Ferry, Idaho peaked during May and June. Average annual peak flow was about 75,000 cubic feet per second (75 kcfs). The peak runoff period tended to be concentrated over several weeks, followed by rapidly decreasing flows to base flows of generally less than 10 kcfs by mid-August.

According to Perkins Geosciences (2004):

> *Significant agricultural activity in the Kootenai valley started in the 1880s when W.A. Baillie-Grohman began to drain wetlands for farming in Canada. Construction of dikes and draining of wetlands to allow farming continued throughout the early portion of the 20th century.*
>
> *By 1931, nine drainage/diking districts had already constructed levees, drainage ditches and pumping stations "for the reclamation and protection of about 22,000 acres of land" in the Kootenai Flats area in Idaho (House Document No. 157, 1931; cited in Pick 1991). This is confirmed by aerial photographs from 1932, which show levees along most but not all banks of the river below Deep Creek. The portion of the river between Deep Creek and Bonners Ferry appears to have been completely leveed by 1932. Setback levees above Bonners Ferry in the braided portion of the river were also constructed by 1932. This portion of the river was also constrained by construction of the railroad embankment around the turn of the century. Approximately 7 more diking districts were formed later, resulting in some level of protection by levees of 94 percent of the land in Kootenai Flats by the end of the 1940s (Pick 1991).*

Historically, the primary crops were grains, cover crops (hay, alfalfa, clover), and other annually planted species. Groundwater conditions under pre-dam conditions are unknown. Construction of drainage canals and pumping systems helped control groundwater and drain land for agricultural use. High groundwater levels likely occurred during the spring runoff, with groundwater dropping as the river and tributary flows rapidly decreased through the summer. To a certain extent, high groundwater levels may have played a role in determining the types of crops grown in the valley, particularly in low-lying areas where seasonally high water tables were likely.

2.2 Post-Dam Conditions

Between dam construction and when Libby Dam began to augment spring flows for sturgeon, agricultural impacts due to high groundwater were minimal (HDR 2003). Since the early 1990's, Libby Dam has provided higher flows in the spring and summer that are intended to benefit threatened and endangered species and growers have indicated that the duration and magnitude of these fish flows adversely affects farm operations in a number of ways, including loss of crops and/or reduction in crop yield. Reaction to these impacts by the growers have been somewhat varied but have not resulted in significant changes in the types or acreages of crops being grown in the Valley.

According to Farm Service figures, since 1998 an average of approximately 30,000 acres has been involved with farm operations (including Conservation Reserve Program or CRP lands; HDR 2003). Areas of agricultural production are shown on Figure 1. The following annually harvested crops are grown in the valley :

Alfalfa	Barley	Bluegrass	Brome	Canola	Mustard
Oats	Peas	Soybeans	Timothy	Wheat	

In addition, Elk Mountain Farms grows hops on two separate farms. Backwoods Farm grows approximately 1200 acres of hops on the west side of the valley in Drainage District 16 and the Tavern Farm grows another 550 acres near the Canadian border in Drainage District 8. Elk Mountain Farms, a subsidiary of the Anheuser-Busch Company, was established in the mid-1980s.

Threatened and endangered fish populations in the Kootenai River and the Columbia River basins (Kootenai River white sturgeon and bull trout, and several Columbia River salmon and steelhead stocks) benefit from certain high flow periods, which historically were provided by natural runoff patterns driven by snowmelt and rainfall. Since the early 1990’s, the Corps has operated Libby Dam to augment flows under a variety of operational actions in an effort to provide flow at sufficient levels and durations to benefit the threatened and endangered fish in the Kootenai River and Columbia River basins. Fish flow operations increase dam discharges during the spring and summer, which result in relatively higher river flows and stages during the prime agricultural season. These higher river flows and stages have the potential to alter groundwater levels by direct influence on the water table and indirect influences on drainage of valley bottom areas via tributaries and constructed drainage features (i.e. drainage ditches, pump facilities). Local farmers and various Corps studies have reported adverse impacts from high groundwater levels in the period since the start of fish flow operations. 1996 and 1997, two wet years with high snowmelt runoff through the spring and summer, resulted in notable adverse agricultural impacts in the Kootenai Valley in Idaho. This study estimates the economic impacts of high groundwater levels on agricultural related to several different Libby Dam operations.

Through the provisions of Section 7 of the Endangered Species Act, the structure of the various fish flows has been formalized since the early 1990s. In their 2000 Biological Opinion for operation of the Federal Columbia River Power System (FCRPS), including Libby Dam, the U.S. Fish and Wildlife Service (USFWS) recommended actions that would modify dam operations and river flows for the conservation and recovery of threatened Columbia Basin bull trout and endangered Kootenai River white sturgeon. The 2004 Updated Proposed Action that supports the 2004 NOAA Fisheries FCRPS Biological Opinion also details a variety of operational actions that would modify river flows for conservation and recovery of threatened and endangered Columbia Basin salmon and steelhead. Implementation of alternative flood control and fish flow operations at Libby Dam is a key component of both the 2000 USFWS FCRPS Biological Opinion and the 2004 Updated Proposed Action. As an action agency responsible for Libby Dam operations, the Corps is investigating the potential effects of various combinations of flood control and fish flow operations.

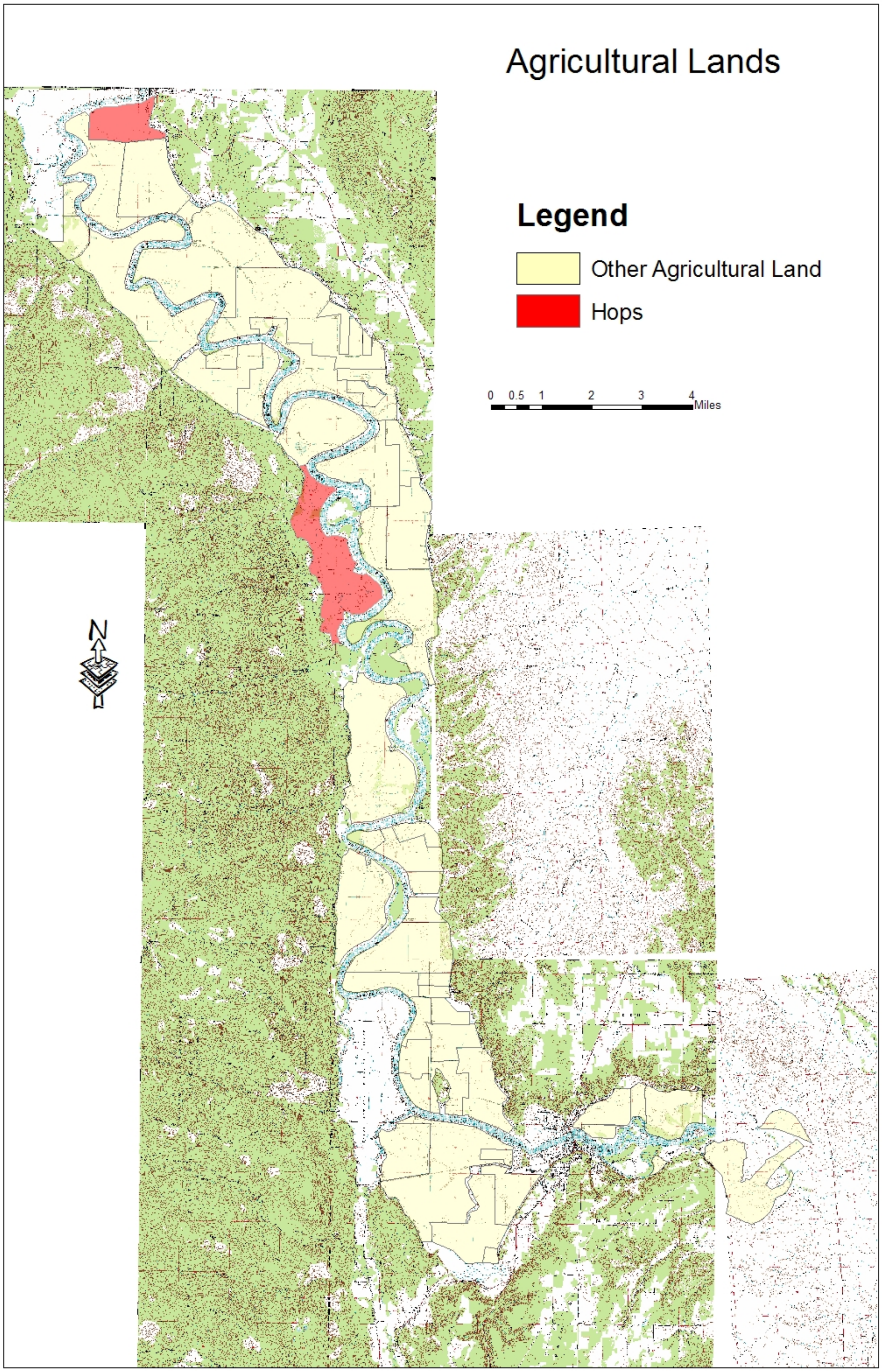
As recommended in the Biological Opinions (BiOps), variable discharge flood control (or VARQ FC, with Q representing engineering shorthand for discharge) is proposed to replace Standard FC at Libby Dam. Compared to Standard FC, VARQ FC procedures require less system flood control space be made available at Libby Dam prior to spring runoff in many years. In years where the April-August seasonal water supply forecast is between about 80 and 120 percent[2] of average at Libby Dam, the reservoir elevation typically would be higher for VARQ FC during the draw-down period from January through April. During reservoir refill, dam outflows under VARQ FC vary based on the water supply forecast (hence, the name variable discharge or VARQ). Because some water that would be stored during the refill period under Standard FC is instead passed through the dam, the amount of storage space needed for flood control can be reduced without compromising system flood control. In years where the seasonal water supply forecast is high (above about 120 percent of the average volume at Libby Dam), storage space for flood control and outflows during refill would be the same for either VARQ FC or Standard FC.

Although VARQ FC does not specifically include flow augmentation for fish, implementation of VARQ FC at Libby Dam enables the Corps to more reliably supply spring and summer flows for fish while simultaneously better ensuring higher reservoir elevations in the summer. These summer flows for fish include flow augmentation for sturgeon, bull trout, and anadromous salmon and steelhead. The volume of water available for sturgeon flows is based on the seasonal water supply forecast with less water dedicated to sturgeon in drier years. The sturgeon flows typically occur in May and June and involve high dam discharges designed to cue sturgeon spawning, egg incubation, hatching, and survival of larvae and juveniles. Bull trout minimum flows, also based on the seasonal water supply forecast, are specified for June through August and represent the lowest allowable dam discharges during this period. Salmon flow augmentation typically occurs during July and August and involves dam discharges necessary to draft Lake Koocanusa to elevation 2439 feet by August 31.

Currently, Libby Dam operates using VARQ FC on an interim basis and provides sturgeon, bull trout, and salmon flows. Sturgeon flows are currently limited to the Libby Dam powerhouse capacity (about 25 kcfs) plus an additional 1 kcfs of spillway flows (the maximum that can be spilled without exceeding the Montana State standard of 110% total dissolved gas saturation). The UCEIS will evaluate six operational scenarios, including the current operation, to inform a decision on implementation of flood control and fish flow operations on a long-term basis.

[2] For forecasts greater than 120 percent of average. Libby Dam typically does not achieve the draft required by either VARQ FC or Standard FC. This is because Libby Dam outflows must be reduced to comply with the International Joint Commission (IJC) Order of 1938 concerning Kootenay Lake levels.

Figure 1. Map of Agricultural Areas in the Kootenai Valley



3.0 STUDY SUMMARY

3.1 Characteristics of the Kootenai Valley Agriculture

3.1.1 Information/Data Flow

Under contract with the Seattle District Corps, HDR Engineering, Inc. prepared a detailed report describing characteristics of Kootenai Valley agriculture and agricultural practices. This report serves as a foundation of our evaluation of the impacts of high groundwater on agricultural economics in the valley (HDR 2003). The report describes the locations and estimated sizes of observed seepage areas, the location and alignment of ditches and pumping facilities, and the characterization of soil types which supported the development, calibration, and validation of the groundwater model. Information on crop distribution and location, grower characteristics, and agricultural practices (crop rotation, pumping, chemical application) supported the economic analysis.

The following summarizes key findings of the report on characteristics of Kootenai Valley agriculture.

3.1.2 Methods

Information on agriculture in the Kootenai Valley was collected from field interviews with growers, previous reports, aerial photographs, and information that could be obtained from agencies such as the Natural Resources Conservation Service (NRCS) and the U.S. Geological Survey. Mapping was accomplished during grower interviews and recorded using handheld Geographic Positioning System units and range finders. Tasks accomplished included identification of the types and acreages of crops in the valley, identification of agricultural practices relevant to high groundwater or soil moisture conditions, assessment of historical crop impacts due to high groundwater levels or soil moisture conditions, and mapping of areas of observed crop impacts from high groundwater levels.

3.1.3 Crops

Growers indicated that temperature is a limiting factor for types of crops that can be grown in the valley. Based on crop type, the interaction of precipitation, drainage, and groundwater levels plays a major role in determining eventual crop yield – the degree and timing of ground moisture conditions can make the difference between a high crop yield and a low crop yield.

With the exception of hops, crops are rotated from season to season and from year to year. Crop rotation planning is generally centered on the primary cash crop of winter wheat. Growers factor the profitability of rotation crops into their planting between winter wheat crops. Table 1 summarizes the average annual acreage of crops in the valley. On average, wheat, barley, alfalfa, canola, and grass/hay make up nearly 90% of the crops grown in the valley.

Table 1: Average Acres by Crop in Kootenai River Valley, 1998 to 2003.

Crop	Average Acres	% of Total Acres
Winter Wheat	9,385	31.2%
Spring Wheat	8,010	26.6%
Barley	3,910	13.0%
Other[1]	3,123	10.4%
Hops	1,711	5.7%
Canola	1,611	5.4%
Alfalfa	1,491	5.0%
Timothy	839	2.8%
Total Acres	**30,080**	**100.0%**

Source: Natural Resource Conservation Service, Bonners Ferry, ID
[1] 'Other' category includes acres of all crops not presented in the table [See HDR, Inc. (2003)].

3.1.4 Agricultural Practices

In the valley, drainage districts were formed in the early 20th century to maintain the levees, drainage ditches and pump stations. Most of the districts have concentrated on intercepting groundwater using either permanent or temporary ditches in the fields, then running the water in open ditches to a pump plant to be pumped to the river. These systems appear to have been set up to primarily address the local flowage from the surrounding mountains or precipitation. The growers have noted that with higher sustained flows in the river, high river stages become a key contributor to waterlogging. A number of drainage systems in the valley cannot adequately function during periods of peak runoff, high river stages, or both.

In several of the drainage districts, the restoration of wildlife habitat on some parcels has included removal of the drainage ditches that intercepted the smaller tributaries. At these locations, shallow water ponds have formed along the edge of the valley that appear to remain year round. In one such case, the grower estimated that each year the ground adjacent to the pond that is too wet to farm increases in extent by approximately 100 feet laterally. It is not clear if the water surface of the pond is increasing in size each year or if the increase results from the subsurface effects from the pond. Nor is it clear what the potential interaction is between the shallow pond and river stages.

The effects of waterlogging include crop losses resulting from ponded water, reduced yields caused by high soil moisture content, high soil moisture content that prevents farm equipment from traveling over the ground, increased costs associated with working around affected areas, and loss of investment when areas are affected after the application of fertilizers and pesticides. Areas that cannot be sprayed because equipment cannot be driven across waterlogged areas can harbor disease and insects. These areas can re-infect the remainder of the crop and cause increased costs if the grower is forced to re-apply chemicals to the remainder of the field. Also, farmers can be forced to operate with a buffer zone around the areas of waterlogging to avoid becoming "stuck" in the mud. This can result in the loss of portions of the crop outside the waterlogged area.

Many areas that have had problems with waterlogging are being planted with crops that are more tolerant of higher soil moisture contents, but even in these areas there can be evidence of crop loss due to elevated ground water levels.[3] However, most growers are reluctant to pursue alternative crops that would be more tolerant of high moisture conditions. Reasons range from the cost of purchasing new equipment that would be required for a crop that is significantly different from what they are growing now, to memories of past efforts that have failed.[4] Growers are not necessarily opposed to using alternative crops that would be more tolerant of higher moisture contents, but likely require clear evidence that the crop will be profitable before they would be willing to switch from more traditional crops or types.

The tenacity and optimism of the growers plays a role in how growers farm likely waterlogged areas. There are areas in the valley where the growers have identified a high potential for impacts from waterlogging to the crop at that location, but the surrounding field exhibits either no such problem or a limited impact from high soil moisture. In some cases, the growers have elected to plant these areas despite the probability of either reduced yields, loss of crop, or increased operating costs. Reasons given for planting these areas vary from determining that diverting equipment around the area would cost more in increased fuel costs than the potential loss of crop, to a belief that the conditions in some years will be sufficient to get a harvestable crop from the area.

3.1.5 Observations and Implications of High Groundwater

High groundwater levels and precipitation can impact crops in two general ways. In some instances, high ground water levels can increase soil moisture content significantly in an area so that infiltration of rainfall is severely restricted. Alternatively, areas may remain wet for longer periods of time after a rainfall event when ground water levels are high. High ground water levels can reduce the soil infiltration capacity enough that even small amounts of rainfall will result in standing water that will drown out crops.

Average elevations within agricultural areas range from approximately 1,750 feet (Drainage District 8 near the Canadian border) to 1,765 feet (Drainage District 2 near Shorty's Island and 3 upstream of Bonners Ferry). The growers indicated that even if the river stage reached an elevation of 1,764 feet at Bonners Ferry, they would see minimal impacts from waterlogging if the river remained at that level for a week or less and then dropped to a stage at or below 1758 feet at Bonners Ferry. However, growers start to see some impacts from waterlogging if the stage at Bonners Ferry exceeds 1758 feet for two weeks; if the duration lasts three weeks or more, the impacts are significantly greater.

[3] A number of growers grow a grass crop in certain areas not suitable for other crops due to impacts from waterlogging, areas where surface runoff tends to collect, or some combination of these factors.
[4] Attempts have been made to grow rice in the valley, but the crop was lost to birds, leaving a negative experience that is easily recalled by the growers.

Mapping of seepage areas during recent years identified over 150 distinct locations covering 1,990 acres throughout the valley (see Plates 12-16 from HDR (2003) in Appendix A). Areas with concentrations of delineated seepage areas are noted in Table 2 (arranged from upstream to downstream areas).

Table 2. Drainage Districts with Concentrations of Delineated Seepage Areas

Drainage District	Location	Affected Grower(s)	Crops Currently Grown
2	North side of the river just upstream of Bonners Ferry	Michalk (Fry Creek Farms)	Wheat, barley, alfalfa hay, timothy hay, soy beans
1	South side of the river between Bonners Ferry and Deep Creek	Figgins, Peterson, Copeland	Wheat, timothy hay, barley
11	East side of the river between the Kootenai Tribe of Idaho reservation and Shorty's Island	Hubbard, Iverson	Wheat, barley, alfalfa hay, timothy hay and seed, canola, potatoes, bluegrass
3	West side of the river adjacent to Shorty's Island	Day Farms	Wheat, barley
16	West side of the river straddling Farnham Creek	Elk Mtn. Farms (Backwoods Farm)	Hops
9	West side of the river at the Copeland bridge	Amoth	Wheat
13	West side of the river south of Parker Creek	Olmsted	Wheat, timothy hay, canola, oats/peas mix
8	East side of the river near the Canadian border	Day Farms, Jantz	Wheat, barley, canola, clover

In general, observations of crop impacts and mapped seepage areas are limited to areas with visible characteristics such as wet ground, stunted growth and/or plant discoloration. Areas with more subtle reductions in crop yield are likely more extensive than the seepage areas identified based on field observations by growers. Also, a number of locations where the ground appears to have relatively low moisture content can exhibit evidence of crop loss.

In general terms, the southern part of the valley appears to have more gravels and sands, resulting in a much quicker response of ground water level to changes in river stage than is experienced in the northern portions of the valley where the soils are typically silts and clays. The growers noted that there is a complex network of subsurface drainages formed by gravels and sands that were deposited by either tributary drainages of the Kootenai River or by the Kootenai River over geologic time; it is their opinion that these subsurface features appear to have significant influence over where and how quickly waterlogged areas respond to a change in the river stage.

3.2 Agronomy

3.2.1 Information/Data Flow

Under subcontract with HDR, Glen Murray, an agronomist, prepared a report that details how water table depth, duration of waterlogging, precipitation events, crop species, crop growth stage, and crop nutrition have affected crop production worldwide (Murray 2003). Results were then applied to crops grown and conditions in the Kootenai River valley to develop relationships between depth-to-groundwater at specific durations and crop yield reduction, by plant growth stage.

Agronomic information on crops grown in Kootenai valley supports the processing of groundwater model output by providing thresholds for when certain groundwater levels at specified durations reduce crop yield. Using these relationships, the model output was sorted to identify how much of the valley (on a proportional basis) might experience adverse effects from seepage. The sorted output then provided a primary input to the economic analysis. The economic analysis relied heavily on the yield reduction functions to quantify the potential economic impact due to different groundwater conditions.

3.2.2 Methods

Information from Boundary County producers and other local and regional experts, together with published literature, were the key ingredients used to determine how high groundwater levels affect yields of the crops grown in the valley.

3.2.3 Results

Water table depths less than 2 feet will likely cause 10% to 100% yield reduction to most crops in most years. As duration and frequency of such waterlogging increases and water table depth becomes shallower, crop losses increase. The stage of plant growth affects its tolerance to waterlogging. For the major crops grown in the Kootenai valley, tolerance to waterlogging, from most to least tolerant, is generally:

1. Grass Hay
2. Alfalfa Hay
3. Timothy
4. Winter Wheat
5. Spring Canola
6. Spring Wheat
7. Spring Barley
8. Hops

For several crops, reductions in crop yield are dependent on the stage of crop development when waterlogging occurs (Murray 2003). For example, spring wheat is very vulnerable to short duration, very shallow groundwater levels during its germination period (defined as April 15 through May 1). During germination, groundwater that is shallower than 1 foot depth for 1 week or more will cause complete loss of the crop. During stem extension after germination (defined as May 1 through June 30), spring wheat is more tolerant of waterlogging and can tolerate groundwater at the surface for:

- One week with a yield reduction of 40%,
- Two weeks with a yield reduction of 50%, and

- Four weeks with a yield reduction of 70%.

Basically, areas that stay wet for longer lead to larger crop losses (i.e. yield reduction increases as the duration of waterlogging increases).

Additionally, for any given duration, crop losses aren't as severe in areas where groundwater is deeper and farther away from the surface root zone (i.e. as the depth-to-groundwater increases, the yield reduction for a given duration generally decreases). For example, hops would have 25% less yield when groundwater remains at one foot depth for two weeks, but would have only 15% less yield when groundwater is at a depth of two feet for two weeks. Murray (2003) details the relationships between the crop-specific development periods, depth-to-groundwater/duration combinations, and yield reduction.

3.3 Groundwater Model

3.3.1 Information/Data Flow

The Corps assembled a computer model to simulate daily groundwater elevations throughout the Kootenai Valley in Idaho under six different dam operational scenarios. The groundwater model output provides the depth-to-groundwater at more than 80,000 locations spread throughout the valley. This raw output was processed to sort out which nodes would have shallow groundwater for long enough to reduce yields of crops grown in the valley (see Section 3.4.2, and Harp and Darden 2005).

The processed groundwater model output provided the inputs for the economic analysis (Harp and Darden 2005). Although outside of the scope of this study, other uses of the groundwater model could include evaluation of options to avoid or minimize seepage (i.e. dam operations, drainage improvements) or impacts from seepage (i.e. avoidance of potentially wet areas given a particular dam operation and drainage system).

3.3.2 Methods

Computer Model Code: The groundwater modeling computer code FEMWATER (Linn et al, 1997) was used for the groundwater model of the Kootenai Valley. Pennsylvania State University and the U. S. Army Engineer Waterways Experiment Station (WES) developed FEMWATER under a cooperative research agreement between the U. S. Environmental Protection Agency (EPA) and the U. S. Department of Defense (DOD).

Model Structure: The area subject to the model included the valley bottom and terraces from 3 miles north of the Canadian border to about 5 miles upstream of Bonners Ferry, and into the Deep Creek Valley for about 8 miles south of the Kootenai River.[5] Observations and data used as fixed inputs for the model included soil and bedrock characteristics and ground elevations. Inputs for the model that varied over time included precipitation, and stage (water surface elevation) at selected points along the Kootenai River and tributaries. The model simulated daily groundwater elevations at discrete locations (nodes) distributed approximately every 600 feet across the modeled area.

Calibration: Model calibration involved running the model using:

- Observed conditions in 2002-2003 with observed groundwater levels provided by the U.S. Geological Survey in wells installed in the floodplain (Campbell 2003) as the calibration target.
- Observed conditions in 1996-1997 with reported soil waterlogging locations from HDR (2003) as the calibration target. This water year was used as a validation tool for the project

After calibrating to 2002-2003 to provide the best fit to observed conditions, the validation of 1996-1997 conditions predicted waterlogging in the vicinity of about 80 percent of surveyed waterlogging locations. The model was unable to predict waterlogging at about 20 percent of the surveyed locations, even when the model was adjusted to encourage high groundwater levels at these locations. These results indicate that the waterlogging in these areas is caused by factors other than groundwater flow (i.e. infiltration of surface water from runoff or precipitation) or that the model resolution is too coarse to simulating localized subsurface features. The model also showed some waterlogging in areas which were not reported by HDR (2003). Total waterlogged acreage throughout the valley bottom appeared similar to the total area of surveyed waterlogged areas reported by HDR (2003).

Predictive Simulations: The seepage study required evaluation of the effects on agricultural production from a range of different dam operations, some of which have no historical precedent. The groundwater model provided a method to simulate how the various dam operations might affect the Kootenai River, Kootenay Lake, and groundwater levels throughout the valley.

Under facilitation of the Kootenai Valley Resources Initiative (KVRI), the Corps worked with local officials, USFWS, tribal staff, and property owners to select two water years[6] representing conditions of interest to the valley stakeholders and relevant to the seepage issue. In selecting two representative years, the Corps recognized that the stakeholder groups strongly preferred that more than two years be modeled if the project schedule and budget allowed.

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[5] The geographic area covered by the model is larger than the valley bottom agricultural areas that were of primary interest. This design allows the economic analysis to avoid use of model output that could be unduly influenced by assumptions of boundary conditions near the margins of the modeled area.

[6] The water year runs from October through September. Thus, water year 1961 begins October 1, 1960 and ends September 30, 1961.

Water year 1964 was selected to represent a typical year, which was defined as a year with a May 1st Libby seasonal water supply forecast between 6.0 and 6.7 million acre-feet[7], with a relatively small May 1st forecast error, and hydrograph timing and volume similar to the 50% exceedance summary hydrograph. 1964 had a seasonal runoff of 6.9 million acre-feet (111% of average, with a May 1st forecast of 6.7 million acre-feet).

Water year 1961 was selected to represent "a more significant year," which was defined as a high-water year that is a cause of concern for the community. The high-water year was chosen solely by the stakeholder group from the period of record as the one year they wanted modeled to capture the upper bounds of seepage impacts. 1961 had a seasonal runoff of 7.9 million acre-feet (126% of average) and a May 1st forecast of 7.5 million acre-feet. Forecasts for 1961 in January, February, March, and April were all lower than the May 1st forecast. The greatest difference in river flows and resulting groundwater levels between VARQ and Standard FC would be expected in years such as 1961 with increasing water supply forecasts through the winter.

The predictive simulations consisted of groundwater model runs for each of the six operational scenarios which were completed for each of the two selected years (1964 as typical, and 1961 as significant), for a total of 12 model runs and output data sets. The predictive groundwater model simulations used Kootenai River and Kootenay Lake stages generated by simulation of the six Libby Dam operational scenarios (see Corps 2004 for complete details of this hydro-regulation modeling) as the primary input that varied between model runs. The hydro-regulation modeling operated Libby Dam to avoid exceeding a river stage of 1764 feet at Bonners Ferry whenever possible.[8] For each separate year, the same tributary stages and precipitation were used for all model runs. The six Libby Dam operational scenarios are described in Table 3.

More details on the construction of the groundwater model is provided in the report titled *Kootenai Flats Seepage Analysis – Groundwater Modeling Report* (Corps 2005)

[7] The average April-August water supply for Libby is 6.25 million acre-feet (MAF).

[8] Actual river stages in 1997 and 2003 never exceeded 1764 feet at Bonners Ferry. Simulated river stages for the 6 different Libby Dam operations for 1961 and 1964 also never exceeded 1764 feet at Bonners Ferry.

Table 3. Libby Dam Operational Scenarios Simulated By the Groundwater Model

Operational Scenario	Description of Dam Operations
LS - (Scenario 1) Standard Flood Control (FC) without Fish Flows	The flood control procedure currently authorized for long-term use is referred to as Standard FC. Standard FC was the method used at Libby Dam prior to and through calendar year 2002. To determine the required flood control operation at Libby, the Standard FC storage reservation diagram (SRD) is used in combination with Libby's seasonal water supply forecasts to determine how much space needs to be made available by 15 March for flood control. As the season progresses and the forecasts change, so do the storage requirements. During refill, the assumed outflow from Libby is 4,000 cubic feet per second (cfs). There is no flow augmentation for fish in this scenario.
LV – (Scenario 2) Variable Discharge (VARQ) FC without Fish Flows	VARQ FC is the flood control method being used on an interim basis at Libby Dam, and recommended for long-term implementation in both the 2000 USFWS FCRPS Biological Opinion (USFWS, 2000) and the 2000 NMFS FCRPS Biological Opinion (NMFS, 2000). This interim operation began in January 2003. Similar to Standard FC, VARQ FC also requires a SRD in conjunction with the water supply forecast to determine the flood control space needed. As the season progresses and the forecasts change, so do the storage requirements. However, as compared with the Standard FC SRD, the VARQ SRD requires less flood control space in years with slightly-below- to slightly-above-average water supply forecasts. During refill, the outflow from Libby varies (hence the name variable discharge or "VARQ," with Q representing engineering shorthand for discharge), and is almost always greater than 4,000 cfs. There is no flow augmentation for fish in this scenario.
LS1 – (Scenario 3) Standard FC with fish flows at powerhouse capacity *(operation prior to 2003)*	In addition to following the Standard FC rules (described for LS – Scenario 1), fish flows were modeled as follows: First, provide a tiered volume of water during the spring freshet for sturgeon spawning and recruitment, using only the maximum powerhouse capacity (about 25,000 cfs). Next, make sure Libby outflow is greater than or equal to the minimum bull trout flow during July and August. Finally, draft the pool to elevation 2,439 feet (20 feet from full) for salmon flow augmentation during July and August. An effort was also made to minimize the impact of a "double peak" – that is, ramping down between sturgeon flows and salmon flows was avoided if for only short periods.
LV1 – (Scenario 4) VARQ FC with fish flows at powerhouse capacity *(operation since 2003)*	Identical to LS1 – Scenario 3, except the VARQ flood control procedure (described for LV – Scenario 2) is followed instead of the Standard FC procedure.
LS2 – (Scenario 5) Standard FC with fish flows at powerhouse plus 10,000 cfs additional flow capacity	Identical to LS1 – Scenario 3, except that now sturgeon flows are provided using the powerhouse capacity plus 10,000 cfs additional capacity, for a total of about 35,000 cfs.
LV2 – (Scenario 6) VARQ FC with fish flows at powerhouse plus 10,000 cfs additional flow capacity	Identical to LV1 – Scenario 4, except that now sturgeon flows are provided using the powerhouse capacity plus 10,000 cfs additional capacity (about 35,000 cfs total).

3.3.3 Results and Limitations

In general, the following observations can be made from the predictive simulations and the calibration runs:

- Modeled water level elevations drop steeply from near 2200 ft at the base of the mountain slopes to below 1800 ft at the edge of the floodplain.
- Water levels tend to be relatively flat below the flood plain, due to the combined effects of the Kootenai River and the agricultural drainage systems.
- Predicted water levels patterns near the Kootenai River closely resemble the stage hydrographs input for the river.
- Predicted water levels at locations distant from the river are higher compared to levels near the river, with broader seasonal peaks compared to locations near the river.
- Predicted water levels at some locations near the valley margins appear not to be affected by the Kootenai River, and instead appear likely due to other causes than groundwater flows (i.e. ponding, precipitation, surface runoff, tributary stages).
- Drains have a strong influence on water levels at some locations, and create depressions in the groundwater surface. In the absence of agricultural drains, acreage of waterlogged areas would be substantially larger than currently observed.
- Groundwater levels for the 1961 simulations during the spring-summer runoff period are clearly higher than the levels for the corresponding 1964 simulations. This is expected since 1961 was selected to represent a relatively wetter year. Precipitation during both water years, with 31.7 inches in 1961 and 28.6 inches in 1964, was above the average precipitation of 22.1 inches/year.
- In 1961 (a wetter year), all the VARQ FC scenarios (LV, LV1, and LV2) result in higher groundwater levels for longer duration than any of the Standard FC scenarios (LS, LS1, and LS2). In part, this results from almost identical river stages under all the VARQ FC scenarios because flood control operations drive dam operations under VARQ FC in the 1961 simulations (i.e. the timing and magnitude of river flows, or hydrograph, is essentially the same for all VARQ FC scenarios).
- In 1964 (a more typical year), fish flows appear to influence groundwater to a greater degree than flood control operation. Groundwater levels are lowest for scenarios without fish flows, midrange for fish flows to powerhouse capacity (LS1 and LV2), and highest for fish flows to 10,000 cfs above powerhouse capacity (LS2 and LV2). LV results in clearly higher groundwater levels for longer duration than those under LS, but groundwater levels and durations for a given fish flow operation are similar between the two flood control operations.

The groundwater model is a useful tool for the purposes of the seepage study, but is subject to some limitations:

- Primarily because of scale and the approximately 600-foot spacing between nodes, the model allows general assessment of groundwater impacts due to river stages across the valley, but should not be used as a predictor of exact groundwater levels at precise locations.
- Simulated flooding or waterlogging near some tributaries is likely an artifact of linear interpolation between a limited number of locations with known stages that were available as inputs to the model (see Figure 2). Filtering of model output helped diminish the effect of flooding or waterlogging that is the sole result of this interpolation artifact.

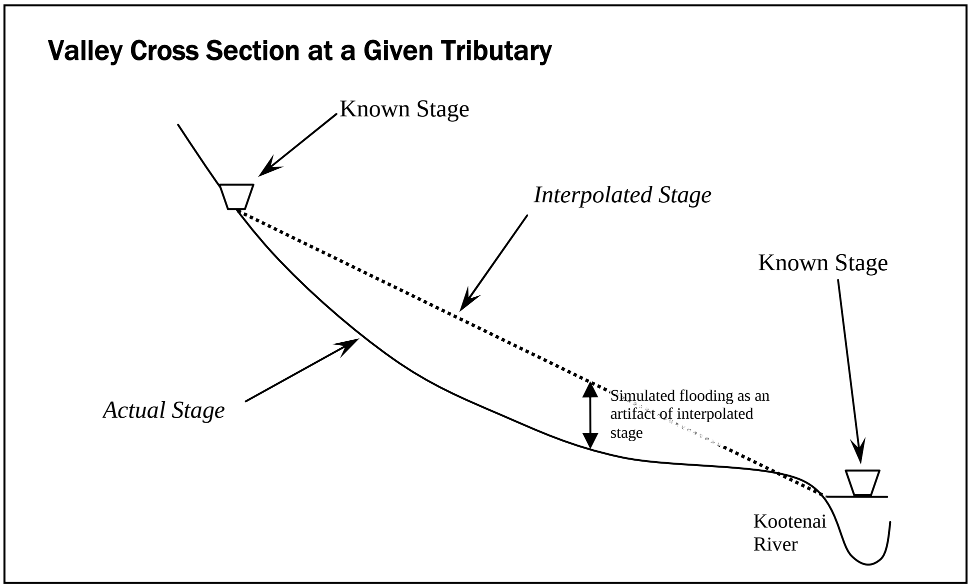

Figure 2. Effects of Interpolation of Tributary Stages

- The model simulates groundwater flow only, and cannot predict flooding or waterlogging caused by precipitation, snowmelt, or surface runoff. However, comparisons of model predictions with observed waterlogged areas can provide a way to estimate where groundwater levels may not be the primary cause of waterlogging.
- The predictive capability of the model is somewhat less at the valley margins than in the center portion of the valley.
- The model predictions of depth-to-groundwater are based partly on ground-surface elevations, so a high precision topographic survey of the valley could help improve the accuracy of the model results.

The full implications of the groundwater model output are summarized the discussion of the economic analysis in Section 3.4.3 below.

3.4 Economic Analysis

3.4.1 Information/Data Flow

The economic analysis produces the final product of the study: the economic impacts of agricultural seepage under the various dam operational scenarios. The integration of the agronomy, groundwater model output, and economic parameters come together to produce estimates of the economic impacts, in dollar values, that allow direct comparison of the different dam operational scenarios. These results are discussed in detail in Harp (2005) and will be summarized in the Upper Columbia Alternative Flood Control and Fish Operations Environmental Impact Statement (abbreviated as UCEIS) in accordance with the National Environmental Policy Act.

3.4.2 Methods

As discussed in Section 3.3, the groundwater model simulates the depth of groundwater at specified locations or nodes distributed across the valley, thus generating a daily record of groundwater depth at each node. When combined with all other nodes in the valley, the groundwater simulation provides a representation of water table fluctuations throughout the valley.

To sort the output, the daily groundwater levels at each node were evaluated to determine if the groundwater remained shallow for long enough to fall within one of the crop yield reduction categories as defined by the agronomic report (see Section 3.2). For example, hops suffer a 90% yield reduction if groundwater is 1-foot below land surface for 28 continuous days. The sorting of the model output counted the number of nodes within the hops producing portion of the valley that met the criteria of 1 foot depth-to-groundwater for at least 28 days. The sorting process classified all nodes in the valley for each category of crop based on crop period (based on time of year), and depth-to-groundwater/duration category.

To avoid "double counting" nodes that could qualify for more than one depth-to-groundwater/duration category, the sorting process was designed to assign a given node to the category with the highest yield reduction category (Table 4).

Table 4. Sorting Protocol for Nodes That Could Fall into More Than One Category

Over a 28 day period, a specific node may have groundwater within 1 foot of the surface for the first 14 days, then groundwater within 2 feet of the surface for the next 14 days. With this pattern, the node could fall into at least 2 different yield reduction categories (for hops in this case):

Depth-to-Groundwater (DTGW)	Duration	Yield Reduction
≤1 foot	14 days	25%
≤2 feet	28 days	60%

For the processed data, the node would be categorized in the highest yield reduction category, with 60% yield reduction, of DTGW of ≤2 feet for 28 days.

Complete details on the sorting protocol are found in Harp and Darden (2005).

Processing of the groundwater model output provided an estimate of the percent (%) of total acreage in the valley with a specific depth-to-groundwater, measured in feet, for a certain period of the year for a defined duration in days. This percent is used to allocate the total acreage of each crop affected at each river stage DTGW-duration category based on the average acres per crop grown in the valley (see Table 1; for example, if 10% of the nodes met depth-to-groundwater/duration criteria to affect yield of hops, the total affected acreage would be 1,711 acres of hops multiplied by 10% to get 171 acres of affected hops).

While this method simplifies calculations, it cannot account for yield losses in the previous crop stages on overall yields in subsequent crop stages (i.e. the winter wheat yield in a specific field could be reduced by high groundwater during March 1 to April 30 - early stem extension, but that yield loss would not be captured as the starting condition for any yield loss during May 1 to August 5 - mid-stem extension). An area with high groundwater during an early period is likely to have high groundwater in following periods. This leads to affected acres being counted more than once. Thus, the estimates used throughout this analysis are the maximum acres the model estimates could be affected.

The processed groundwater model results were combined with the set of yield reductions due to waterlogging for each crop (see Section 3.2 and Murray 2003) and average yield per acre for each crop. This provided a conversion from affected acreage to lost production for each DTGW-duration category by crop development phase.

The lost production figures were then combined with price and cost information to generate an estimate of the monetary value attributed to crop harm that might occur due to groundwater seepage. The aggregate losses to agricultural production in the valley under different conditions are totaled by adding the estimated losses for each crop.

Harp and Darden (2005) detail allocation of costs and lost revenues that were used to generate losses due to high groundwater.

3.4.3 Results

Calibration and Validation of Methods – 1997 and 2003

Based on observed river conditions input into the groundwater model, estimated affected acreage and the associated economic impacts were calculated for the 2003, the calibration year for the groundwater model, and 1997, the validation year for the groundwater model (Table 5). These estimates provide a baseline for the simulations of the six different dam operational scenarios that were completed for 1961 and 1964.

Table 5: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories based on actual river, tributary, and precipitation in 1997 and 2003.

	1997		2003	
Crop	**Affected Acres**	**Loss**	**Affected Acres**	**Loss**
Hops	890	($3,098,418)	342	($1,250,021)
Spring Wheat	4,180	($1,117,040)	2,135	($344,167)
Winter Wheat	4,803	($846,015)	1,778	($362,824)
Barley	2,344	($813,709)	868	($269,730)
Canola	966	($200,601)	358	($66,785)
Alfalfa	946	($125,663)	472	($54,118)
Totals	**14,129 acres**	**($6,201,447)**	**5,953 acres**	**($2,347,645)**

For each crop, 1997, a wet year[9] with a water supply that was 124% of the average for Libby, resulted in more acreage affected by high groundwater levels, higher yield loss, and higher economic impact than occurred in 2003, a dry year.[10] The largest yield losses are associated with longer durations with shallow depth-to-groundwater, conditions which were more frequent in 1997. In both years, hops are estimated to sustain the biggest losses, followed by winter and spring wheat.

Focusing on 1997, the overall estimate of affected acreage is 14,129 acres. This exceeds the estimate of 1,990 acres in HDR (2003) and the 8,000 acres used in previous evaluations of seepage (Harp and Darden 2001; McGrane 1999), but is relatively close to the 13,300 acres estimated in Corps of Engineers (1971). The estimated economic impact in 1997 is also larger than previous estimates: Harp and Darden (2001) estimated losses from seepage at $1.6 million; McGrane (1999) cites local estimates for 1997 seepage losses at $1.44 million.

The higher estimates using the model output may be due to the fact that the groundwater model is capturing all seepage during the growing season. The estimates in Harp and Darden (2001) and McGrane (1999) relied on visual evaluation of crop harm at the peak of seepage and captured only those yield reductions that appeared visually obvious in a crop stand, such as stunted growth or discoloration. Areas that may suffer yield reduction without obvious visual indications are not included in these earlier estimates (HDR 2003). The model captures additional seepage that occurs before and after peak seepage that leads to visual identifiers of stressed crops.

Historically, the most likely time for river stages to be high and remain so for significant periods of time is May and June. For example, in 1997 river elevations began to rise above 1755 feet elevation at Bonners Ferry in early May, stayed above 1760 feet for most of June, and remained above 1755 feet until early July (Corps, 2005). Under the 2003 scenario, the Bonners Ferry gauge rose above 1755 feet at the very end of May and fell below that mark by mid-June (Corps, 2005). In both years, 28-day durations during this period produce significant losses for hops and grains and to a lesser extent for canola and alfalfa. In general, for both years, the time of high water combined with greater

[9] Actual April-August runoff for Libby was 124% of average.
[10] Actual April-August runoff for Libby was 81% of average.

susceptibility of crops to harm at certain stages of their development produces a predictable pattern of losses when comparing months: May and June are generally going to be the months in which harm is most likely to occur and therefore aggregate losses will be highest. And, in years like 1997, high river stages persisting into July can result in continued additional crop losses extending into the early summer.

Unlike 1997, no anecdotal data is available for 2003 to indicate if the $2.3 million in model-simulated losses actually occurred, especially since 2003 was considered a drought year. A possible interpretation is that 2003 represents a baseline case measuring historically forgone yields due to seepage in the valley that is not due directly to dam operations (i.e. it's the cost of farming in the valley). Additionally, the sorting and analysis protocol used to combine the groundwater model output and the yield reduction figures by crop stage tends to provide conservatively high estimates of the aggregate effect from high groundwater. This is an artifact of the inability to account for cumulative yield losses in areas where high groundwater persists throughout the growing season (see Section 3.4.2). It is likely that the loss estimates for 2003 reflect a combination of over-counting of affected acres in the model and baseline seepage effects.

Simulation of the Effects of Different Dam Operational Scenarios on Agricultural Losses – 1961 and 1964

Based on simulated river stages during 1964, the year selected to represent a typical year, and 1961, the year selected to represent a more significant year for agricultural losses, estimated economic impacts were calculated for the six different dam operational scenarios (see Table 3) being evaluated in the UCEIS (results are summarized in Table 6 and

Table 7). Harp and Darden (2005) present the detailed breakdown of affected acres, yield loss, and economic impacts for each crop used to calculate the total aggregate losses.

Table 6: Aggregate Acreage Affected by High Groundwater for Simulated Operational Scenarios of Libby Dam, 1961 and 1964.

		Affected Acres					
Crop	**Year**	**LS**	**LV**	**LS1**	**LV1**	**LS2**	**LV2**
Hops	1961	616	781	690	787	713	787
	1964	302	376	479	485	496	496
Winter Wheat	1961	2,732	3,121	2,940	3,116	3,030	3,116
	1964	1,780	1,957	2,258	2,220	2,342	2,273
Spring Wheat	1961	2,775	3,232	2,961	3,235	3,068	3,235
	1964	1,873	2,123	2,457	2,448	2,544	2,524
Barley	1961	1,354	1,578	1,446	1,579	1,498	1,579
	1964	914	1,037	1,199	1,195	1,242	1,232
Canola	1961	558	650	596	651	617	651
	1964	377	427	494	492	512	508
Alfalfa	1961	593	763	662	773	680	774
	1964	409	464	514	513	516	528
Aggregate Impacts	1961	8,628	10,125	9,295	10,141	9,606	10,141
	1964	5,655	6,384	7,401	7,352	7,653	7,561

Table 7: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories and Dam Operational Scenarios, 1961 and 1964.

		Impact ($)					
Crop	**Year**	**LS**	**LV**	**LS1**	**LV1**	**LS2**	**LV2**
Hops	1961	($2,997,748)	($3,779,747)	($3,502,589)	($3,816,797)	($3,361,387)	($3,816,797)
	1964	($1,523,538)	($1,905,256)	($2,301,418)	($2,327,272)	($2,368,432)	($2,390,710)
Winter Wheat	1961	($521,192)	($627,081)	($557,736)	($629,777)	($565,902)	($629,934)
	1964	($285,381)	($407,297)	($451,084)	($453,075)	($461,636)	($462,066)
Spring Wheat	1961	($615,384)	($724,542)	($656,186)	($726,336)	($664,652)	($726,336)
	1964	($411,237)	($479,141)	($544,364)	($546,539)	($559,144)	($559,375)
Barley	1961	($441,253)	($518,850)	($470,349)	($520,116)	($476,400)	($520,116)
	1964	($294,941)	($343,413)	($390,245)	($391,660)	($400,822)	($400,846)
Canola	1961	($108,142)	($127,399)	($115,330)	($127,717)	($116,820)	($127,717)
	1964	($72,259)	($84,216)	($95,671)	($96,069)	($98,270)	($98,327)
Alfalfa	1961	($30,578)	($39,018)	($34,232)	($39,408)	($35,354)	($39,422)
	1964	($21,254)	($24,536)	($28,091)	($28,150)	($28,140)	($28,998)
Aggregate Impacts	1961	**($4,714,295)**	**($5,816,637)**	**($5,336,422)**	**($5,860,151)**	**($5,220,515)**	**($5,860,322)**
	1964	**($2,608,610)**	**($3,243,859)**	**($3,810,872)**	**($3,842,765)**	**($3,916,444)**	**($3,940,323)**

In both 2003 and the LS simulation for 1964, the river did not exceed a stage of 1758 at Bonners Ferry, which represents the anecdotal threshold for the commencement of seepage impacts. For all other model runs and years, the river stages during spring runoff exceed 1758 feet at Bonners Ferry, and only one (LV in 1964) has a peak stage that does not exceed 1760 feet at Bonners Ferry. In addition to the similar hydrograph pattern, the loss estimates in both 2003 and the LS simulation for 1964 are between $2 and $3 million. Hence, given the low river stages achieved for 2003 and LS in 1964, together with the similar loss estimates in these two scenarios, it appears that all loss estimates likely include a baseline loss of approximately $2,000,000. Note that precise quantification of the baseline loss figures would require analysis of additional years paired with ground-truthing the modeled loss estimates with actual losses. However, realizing that there is some baseline loss captured in the model, the analysis of the impacts of agricultural seepage focuses on the relative differences between the different operations.

In 1964 (a typical year), the results indicate that the largest impacts to crops are the result of providing fish flows, with relatively smaller differences attributed to the flood control operations or the variations between the two simulated fish flow operations. For example, the differences in impacts between all fish flow scenarios when compared to their respective without-fish-flow operation (i.e. LS1 and LS2 compared to LS; LV1 and LV2 compared to LV) are estimated at $1,200,000 to $1,300,000. But the differences in impacts between LS1 and LV1 are estimated at only $31,000, and at only $24,000 between LS2 and LV2. The increase in maximum sturgeon flow from powerhouse capacity (LS1, LV1) to 10,000 cfs above powerhouse capacity (LS2, LV2) is estimated to increase impacts by about $100,000, regardless of flood control operation. The difference between the most impact (LV2) and the least impact (LS) is estimated at $1,332,000 (or about 50% of the estimated impacts of LS). In summary, in a typical year like 1964, growers would experience similar impacts for a given fish flow operation, regardless of the flood control operation of Libby Dam.

Unlike a typical year such as 1964, the results indicate that the fish flows and flood control operation factor more equally into increasing losses in a significant year like 1961. Instead, the flood control operation drives river stages and resultant differences in groundwater levels. For example, the differences in impacts between LS1 and LV1 are estimated at $524,000, and at $640,000 for LS2 and LV2. The Standard FC scenarios (LS, LS1, LS2) show some of the same patterns as 1964, with the addition of fish flows contributing an estimated $500,000 to $600,000 increase in losses for LS1 and LS2, respectively, when compared to LS. Note, however, that the estimated increase in 1961 losses due to adding fish flows to Standard flood control are about 50% less than the estimated increase in 1964 losses due to fish flows. For all VARQ FC scenarios, flood control drove the 1964 dam operations, so fish flows do not play a large role in crop impacts. For example, the estimated impacts for all of the VARQ FC scenarios (LV, LV1, LV2) are within $43,000 of each other. The difference between the most impact (LV1 or LV2) and the least impact (LS) is estimated at $1,146,000 (or about 25% of the estimated impacts of LS).

In summary, in a more significant year like 1961 where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impact under any of the scenarios, with relatively higher impacts under operations which include VARQ FC operations. As for the VARQ flood control simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations may supersede fish flow considerations.

4.0 DISCUSSION & RECOMMENDATIONS

In a typical year like 1964, growers would experience similar impacts for a given fish flow operation, regardless of the flood control operation of Libby Dam. In these years, total impacts due to high groundwater are estimated to be about 50% higher with fish flows than without. In a more significant year like 1961, where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impact under any of the scenarios, and VARQ FC operations are estimated to generate higher impacts than Standard FC operations. Fish flows are expected to add to impacts in more significant years, but additional losses are estimated at about 10% of total impacts, much less than the relative contribution of fish flows in more typical years. As happened in the VARQ FC simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations would tend to supersede fish flow considerations.

Additional analysis would be necessary to evaluate how the geographic extent of shallow groundwater relates to agricultural impacts. To complete this analysis a typical distribution of crops grown over the valley could be overlaid on the groundwater model output, which is geographically referenced. This would allow more precise identification of seepage impact areas that may extend beyond those areas delineated by HDR (2003) based on visible indications of crop stress. Portions of the valley with specific problems could be targeted by stakeholders in the valley for remedial actions to address high groundwater levels and agricultural impacts. For example, drainage systems could be improved, crops or strains tolerant to shallow groundwater could be planted, or the area could be removed from production under a variety of habitat restoration programs (i.e. the Conservation Reserve Program or Wetlands Reserve Program through the U.S. Department of Agriculture; the Private Lands Restoration Program through the U.S. Department of Interior).

To be effective and sustainable, any strategy aimed at avoiding or minimizing the potential agricultural losses due to high groundwater levels must acknowledge and account for the important role of agriculture in the local economy. Site specific remedies will depend on the characteristics of the groundwater fluctuations, river conditions that are likely to occur over the foreseeable future, agricultural commodity market status, farm profitability, and limits of funding and authorization for pursuing remedial strategies.

The Corps would need specific authorization and funding from Congress in order to pursue and implement remedies for groundwater seepage in the Kootenai Valley. Until that happens, other local, state, federal, and non-governmental stakeholders may be better able to address the issues identified in this study report.

5.0 REFERENCES

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Appendix A

Maps of Seepage Areas in the Kootenai Valley as Identified by Growers

(from HDR, 2003)

[*Note to users of the electronic version of Appendix G. Due to their size, maps for this "Appendix A" can be downloaded separately from the Web site.*]