# Identifying Best Management Practices in Phosphorus Reduction for the Echo Reservoir Watershed

**CEE 6490**

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*Submitted to:*
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## Abbreviations:

- TMDL: Total Maximum Daily Load.
- WBWCD: Weber Basin Water Conservancy District.
- BMP: Best Management Practice.
- DEQ: Department of Environmental Quality.
- DWQ: Division of Water Quality.
- WRF: Water Reclamation Facility.
- WWTP: Wastewater Treatment Plant.

## 1. Abstract

*Following a review of available water quality data [by the Utah Division of Water Quality], it was evident that total phosphorus and dissolved oxygen concentrations at Echo Reservoir exceeded the water quality criterion for the designated beneficial use (Echo Reservoir TMDL WQ Study). To fulfill the requirements of Clean Water Act, a TMDL Program was developed for Echo Reservoir. According to this TMDL Program, phosphorus loads have been allocated to the various existing sources of phosphorus loading to meet a total load of 19,800 kg/yr at Echo Reservoir. Since existing loads produce a much larger value, it is necessary to reduce the loads from the various sources within the Echo Reservoir Watershed. In this project, we attempted to identify appropriate Best Management Practices (BMPs) which can be applied to reduce phosphorus at each source. Based on the cost estimate of the BMPs, the most cost effective and efficient BMPs were selected for each source. The results show that most (88.7%) of the proposed phosphorus reduction from non-point sources are achieved by using BMPs at a cost of* $ 1,022,845.89.

## 2. Introduction

Excess nutrients (phosphorus and nitrogen) stimulate algae growth. Sources of these nutrients include animal wastes, agricultural runoff, and sewage. Excess of algae prohibit light penetration and reduce dissolved oxygen in the water. Lower oxygen concentration affects the aquatic habitat and impact the water consumer. High concentrations of total phosphorus and low concentrations of dissolved oxygen are major problems at Echo Reservoir Watershed (Utah_DEQ 2006). This high concentration of nutrients produces an algae problem within and below Echo Reservoir (Stevens et al. 2006). This problem increases especially during low flow (late summer and fall) on the Weber River. When the level of water drops, the algae die causing taste and odor problems at WBWCD’s treatment plants. Thus, it is necessary to control the excess nutrients at the Echo Reservoir Watershed.

This study is based on the findings of a study (TMDL for Echo Reservoir) which has identified the significant sources of phosphorus loading to Echo Reservoir and allocated acceptable loads for each source within the Echo Reservoir Watershed. This load allocation calls for substantial load reduction from the identified phosphorus loading sources. Therefore it is our goal to identify and recommend ways to achieve proposed load reductions from each source of phosphorus loading.

## 3. Background

In 1977 the US federal government passed a Clean Water Act. This act requires that the water quality of the waters of the United States be maintained and/or restored for their designated beneficial uses. The strategy that has evolved to date to achieve this objective is known as Total Maximum Daily Load (TMDL) Program. A TMDL Program identifies and defines the beneficial use of a water body and specifies the maximum load of pollutant that that water body can receive to sustain its beneficial use. In Utah, the Department of Environment Quality (DEQ), Division of Water Quality (DWQ), TMDL Section is responsible for preparing TMDL Programs for the waters of Utah. This study is based on one of such Programs which the TMDL Section of the Utah DEQ has completed for Echo Reservoir. A table summarizing this study is given in Appendix-A. It should be noted, however, that this Program has not yet been approved by the Environmental Protection Agency (EPA).

## 3.1.Area of Study

Echo Reservoir is located in the southeastern of the Weber River Watershed (Figure 1). The watershed above Echo Reservoir can be divided into nine sub watersheds. Details of the characteristic of each sub watershed are presented in Appendix B.

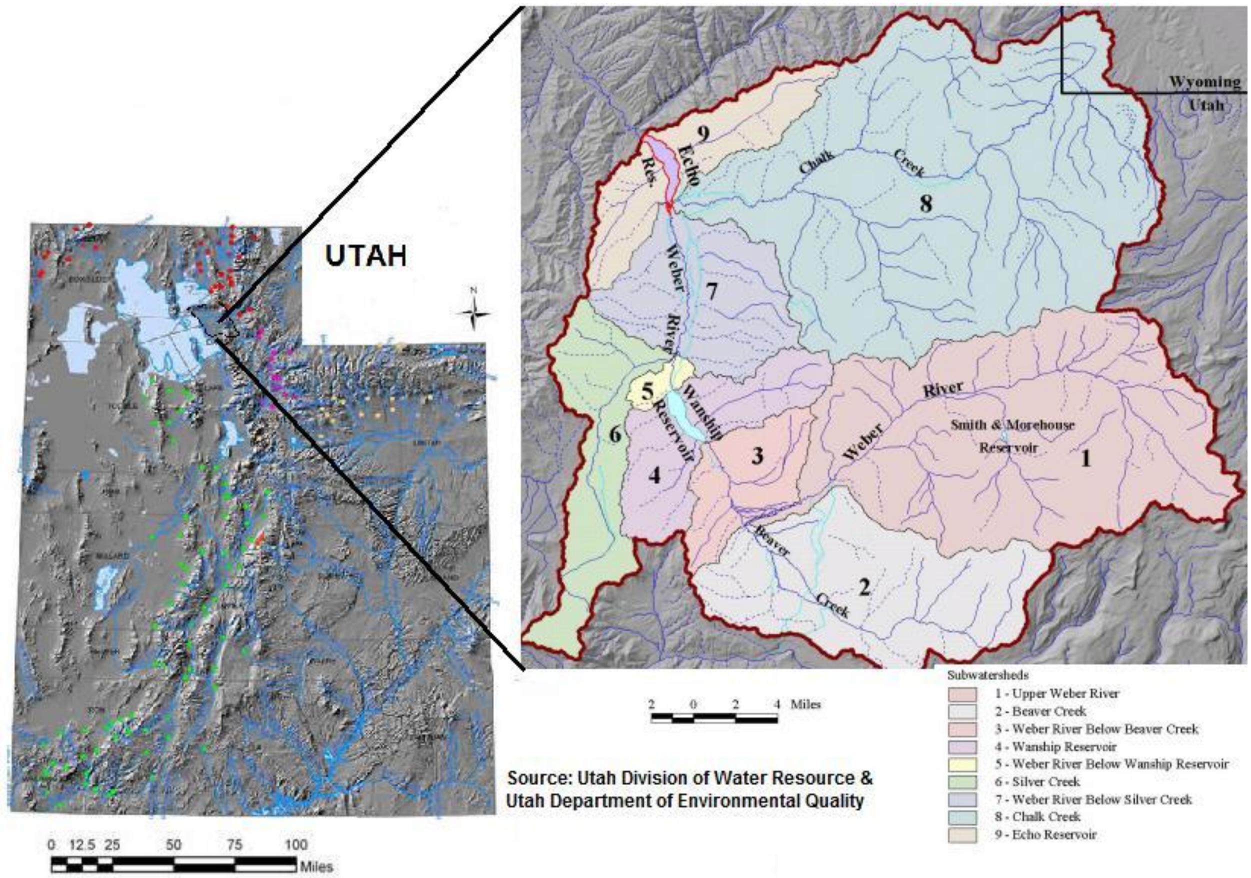


**Figure 1: Location of the Echo Reservoir.**

Echo Reservoir is influenced by the following creeks and rivers: Chalk Creek, Silver Creek, the Weber River, and Beaver Creek as shown in Figure 1. Stream flow in the section of the Weber River between Silver Creek and Echo Reservoir is generally less than 200 cfs in the summer, fall, and winter and is generally less than 600 cfs during the spring.

## 3.2.Significant Sources of Phosphorus Loadings

The study conducted on the Echo Reservoir Watershed in preparation of TMDL Program for Echo Reservoir, identifies the following major sources of phosphorus loading:

- **Animal Feeding Operations (AFOs):** AFOs have been defined in the Code of Federal Regulations 40 CFR 122.23(b) (1) as an area where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility."(TMDL for Echo Reservoir) Animal waste enters nearby water bodies through either of two ways: direct runoff from AFOs or runoff from land applied manure. In Echo Reservoir Watershed, there are 18 AFOs that contribute to phosphorus loading to Echo Reservoir.
- **Grazing:** After an area is grazed with animals it inevitably retains animal wastes that are washed into a nearby water body after runoff. In Echo Reservoir Watershed, there are private as well as public grazing locations that contribute to phosphorus loading to Echo Reservoir.
- **Onsite Wastewater Treatment Systems:** Leakage containing phosphorus occurs from incorrectly installed or failed Onsite Wastewater Treatment Systems to nearby waterways. Within Echo Reservoir Watershed, there are many such systems which contribute to phosphorus loading to Echo Reservoir.
- **Point Sources:** There are five point sources within the Echo Reservoir Watershed that contribute phosphorus loading to the Echo Reservoir. These are the Kamas Fish Hatchery, Kamas Lagoons, Snyderville Basin Silver Creek WRF, Oakley Wastewater Treatment Plant(WWTP), and Coalville WWTP.

- **Diffuse loads from Runoff:** Phosphorus from fertilizers and pesticides from agricultural lands, and from other chemicals left on trails, roads, dispersed camping sites etc is loaded to nearby water body after a runoff.
- **Natural Background:** Phosphorus loading associated with the natural geology of the watershed. This is natural and uncontrollable.
- **Internal Reservoir Loading:** Phosphorus in sediments that has settled to the bottom of the reservoir is loaded back to the water in the reservoir when certain conditions permit. No information is available regarding the phosphorus content or potential phosphorus release rates of the sediments in Echo Reservoir (TMDL for Echo Reservoir). Therefore internal reservoir loading in Echo Reservoir is estimated based on data available from other similar reservoirs.

## 3.3.Permissible Total Phosphorus Loadings

The TMDL Program for Echo Reservoir was developed to achieve certain water quality standards as given in Appendix A. The Echo Reservoir TMDL study provides the maximum loads from each of the major sources mentioned above such that the beneficial water use of Echo Reservoir is restored or maintained. Permissible loadings were evaluated using a model of Echo Reservoir that simulates the major physical, chemical, and biological processes affecting total phosphorus and dissolved oxygen concentrations within the reservoir (TMDL for Echo Reservoir). Once the permissible loads are identified the next step is to allocate those permissible loads to the various sources that have been identified. The process used to allocate pollutant loads between sources in the TMDL study area has considered many factors (TMDL for Echo Reservoir). Some of these include public involvement, existing plans for implementing

BMP/BATs in the study area, cost, projected future load from pollutant sources, and effectiveness of BMPs (TMDL for Echo Reservoir). Currently no load reduction from point sources has been proposed by the TMDL study for Echo Reservoir. Table 1 below shows the proposed load allocation for the non-point source within the Echo Reservoir Watershed to achieve a total phosphorus loading of 19,800 kg/yr at Echo Reservoir. As explained above, Echo Reservoir cannot assimilate phosphorus loads in excess of 19,800 kg per year.

**Table 1: Allocation of Total Watershed Loads showing Non-Point Sources only (TMDL for Echo Reservoir )**

| Non Point Sources | Existing Total Watershed Load (kg/yr) | Existing Total Watershed Load Allocation per TMDL (kg/yr) | Percent Reduction (%) |
|---|---|---|---|
| | **Chalk Creek** | | |
| **AFOs** | 248 | 25 | 90 |
| **Land applied manure** | 961 | 192 | 80 |
| **Public land grazing** | 0 | 0 | 0 |
| **Private land grazing** | 3,535 | 3,182 | 10 |
| **Septic systems** | 24 | 24 | 0 |
| **Diffuse runoff** | 6,539 | 5,624 | 14 |
| | **Weber River below Wanship** | | |
| **AFOs** | 66 | 7 | 90 |
| **Land applied manure** | 942 | 188 | 80 |
| **Public land grazing** | 0 | 0 | 0 |
| **Private land grazing** | 1,550 | 1,395 | 10 |
| **Septic systems** | 135 | 135 | 0 |
| **Diffuse runoff** | 5,493 | 4,944 | 10 |
| | **Weber River above Wanship** | | |
| **AFOs** | 1,181 | 118 | 90 |
| **Land applied manure** | 3,560 | 712 | 80 |
| **Public land grazing** | 196 | 196 | 0 |
| **Private land grazing** | 3,718 | 3,346 | 10 |
| **Septic systems** | 221 | 221 | 0 |
| **Diffuse runoff** | 13,517 | 12,165 | 10 |
| | | | |
| **Total Non Point Source** | **41,886** | **32,474** | **22.5** |

## 3.4.Phosphorus Reduction Strategies

As pointed out in the introduction, the purpose of this project is to identify and recommend ways to achieve the load reductions (Table 1) from each non-point source. In the case of non-point sources, Best Management Practices (BMPs) are used to achieve phosphorus reduction. Recently Bowcutt and Daugs (2008) attempted to derive estimates of BMP costs (Table 2) that are to be more representative of conditions in the Bear River Watershed using Potomac River Watershed cost data and matching these data with Natural Resource Conservation Service (NRCS) BMP price listing information for BMP project implementation capital and operating costs (Horsburgh, et al, 2009.). Since, we were not able to locate similar cost information for BMPs for the Echo Reservoir Watershed, we have used the cost and efficiency information on BMPs provided by Bowcutt and Daugs.

**Table 2: Best Management Practices for Phosphorus reduction from non-point sources (Bowcutt, J. and Nathan Daugs. 2008)**

| No | BMP | Pounds of phosphorus reduction per acre (or linear foot) | Cost per pound of phosphorus reduction ($/lb.)[1] |
|---|---|---|---|
| 1 | **Land retirement** | 1.65/acre | 3,342 |
| 2 | **Grazing land protection** | 0.194/acre | 108 |
| 3 | **Stream fencing** | 0.016/linear foot | 623 |
| 4 | **Stream bank stabilization** | 0.14/linear foot | 7 |
| 5 | **Cover crops** | 0.39/acre | 306 |
| 6 | **Grass filter strips** | 1.28/acre | 187 |
| 7 | **Animal waste facility** | 241.84 per system | 331 |
| 8 | **Conservation tillage** | 0.18/acre | 153 |
| 9 | **Agricultural nutrient management** | 0.39/acre | 76 |
| 10 | **Sprinkler irrigation** | 26/acre | 58 |

[1] Monetary values are in 2008 dollars.

In order to help us identify which BMPs could be relevant in phosphorus reduction from the various sources identified above, we have provided their associated definition in Table 3.

**Table 3: Best Management Practices (BMPs) for phosphorus reduction from non-point sources.**

| No: | BMP | Definition |
|---|---|---|
| 1 | Land retirement | The removal of land from irrigated agriculture. |
| 2 | Grazing land protection | Activities that improve grazing management such as herding. |
| 3 | Stream fencing | Stream fencing refers to constructing fences along the banks of a stream to protect bank degradation which leads to deterioration of the stream water quality. |
| 4 | Stream bank stabilization | Consists of using vegetation of structural material to stabilize and protect bank of streams, brooks, rivers or excavated channels against scour and erosion from flowing water.(Maine Erosion and Sediment Control BMPs, Bureau of Land and Water Quality; Maine Department of Environmental Protection, March 2003) |
| 5 | Cover crops | Planting of various crops such as corn, soybeans etc among other things to protect the land from erosion. |
| 6 | Grass filter strips | Activities that involve creating buffer zones between water bodies and source of pollution with grass |
| 7 | Animal waste facility | Facilities that convert manure to methane. |
| 8 | Conservation tillage | Purposely leaving crop residues in place to reduce erosion |
| 9 | Agricultural nutrient management | Refers to BMPs in agriculture that increase productivity while reducing nutrient loss to the environment |
| 10 | Sprinkler irrigation | Sprinkler irrigation reduces run off from irrigated agricultural lands and provide an efficient way of fertilizer application. |

## 4. Institutional Analysis

Since this project is related to water quality, the major federal and state agencies are mentioned below:

- **US, Environmental Protection Agency (EPA):** The mission of EPA is to protect human health and to safeguard the natural environment -- air, water and land -- upon which life depends (http://www.epa.gov/).
- **Utah, Department of Environmental Quality (DEQ):** The mission of the Department of Environmental Quality is to safeguard human health and quality of life by protecting and enhancing the environment. (http://www.deq.utah.gov/). The Department has a special division to deal with water quality.

- **Utah, Division of Water Quality (DWQ):** The mission of the Division is to protect, maintain and enhance the quality of Utah's surface and underground waters for appropriate beneficial uses; and to protect the public health through eliminating and preventing water related health hazards which can occur as a result of improper disposal of human, animal or industrial wastes while giving reasonable consideration to the economic impact (http://www.waterquality.utah.gov/).

Since the Clean Water Act was issued in 1977, states are required to preserve and protect their water resources. Therefore, when a water body such as the Echo Reservoir is impaired, a TMDL study is conducted to identify problems and propose solutions. In Utah, the DWQ undertakes such a study through its TMDL section. The study is then sent out to EPA for approval and possibly federal grant to implement an implementation plan. The TMDL for Echo Reservoir has not yet been approved.

## 5. Methodology

After studying Table 1 and Table 3, each non-point source was assigned a relevant BMP to achieve the proposed phosphorus reduction as discussed below. This is summarized in Table 4.

- **Direct runoff from AFOs:** According to the TMDL of Echo Reservoir, it was proposed to reduce 90% of phosphorus loading from direct runoff from AFOs. However, based on the available BMPs we could not identify a BMP which can be used to achieve the proposed load reduction. Hence we are not going to deal with this source of pollutant in this report.
- **Land applied manure:** The TMDL of Echo Reservoir proposes an 80% reduction of phosphorus loading from land applied manure. Three BMPs namely: grass filter strips, conservation tillage and agricultural nutrient management were identified to achieve the phosphorus load reduction proposed from land applied manure.

- **Public land grazing:** No reduction of phosphorus loading from public land grazing was proposed by the TMDL of Echo Reservoir. This is so at the existing level of phosphorus loading at the watershed. Hence, it may be necessary to use some BMPs to reduce phosphorus loading from public land grazing at some future time. Three BMPs were identified to reduce phosphorus loading from public land grazing. Since this study is being based on existing phosphorus loading, public land grazing will not be considered for purposes of phosphorus reduction.

- **Private land grazing:** The TMDL of Echo Reservoir proposes 10% reduction of phosphorus loading from private land grazing. Three BMPs namely: grazing land protection, stream fencing and grass filter strips were identified to reduce phosphorus loading.

- **Septic systems:** The TMDL of Echo Reservoir proposes no reduction of phosphorus loading from septic systems. Hence septic systems are not considered for management options to reduce phosphorus loading.

- **Diffuse runoff:** The TMDL of Echo Reservoir proposes 10% - 14% (depending on location) in reduction of phosphorus loading from private land grazing. Seven BMPs namely: land retirement, stream bank stabilization, cover crops, grass filter strips, conservation tillage, agricultural nutrient management, and sprinkler irrigation were identified to reduce phosphorus loading.

Therefore, we will consider the three feasible sources namely: Land Applied Manure, Private Land Grazing and Diffuse Runoff for phosphorus load reduction.

**Table 4: Assignment of applicable BMPs to non-point sources.**

| No: | Sources | Definition | Applicable BMPs |
|---|---|---|---|
| 1 | Direct run off from AFOs | Animal waste is washed into nearby water body by a runoff | None from defined BMPs |
| 2 | Land applied manure | Animal waste applied on agricultural land as a fertilizer that is incorporated into the soil and is washed away into a nearby water body by a run off | BMP6, BMP8, BMP9 |
| 3 | Public land grazing | Animal waste from public grazing land is washed into nearby water body by a runoff(100% for animals between 0 and 10 meters; 10% for animals between 10 and 100 meters) | BMP2, BMP3, BMP6, |
| 4 | Private land grazing | Animal waste from private grazing land is washed into nearby water body by a runoff(25% for animals between 0 and 10 meters; 10% for animals between 10 and 100 meters) | BMP2, BMP3, BMP6, |
| 5 | Septic Systems | Domestic waste that arises from cabins, summer homes and other residences that don't have sewer and use septic tanks that are installed in close proximity to existing water ways or are installed incorrectly or in the event of failure. | None from defined BMPs |
| 6 | Diffuse Runoff | Phosphorus loading that arises from fertilizers, pesticides, trails, roads, dispersed camping sites and erosion from up slopes areas. | BMP1, BMP4, BMP5, BMP6, BMP8, BMP9, BMP10 |

The extent to which phosphorus can be reduced using a specific BMP depends on the available area for BMP application. For example, to reduce phosphorus loading from private land grazing in Chalk Creek Watershed using grazing land protection (a BMP), we need to know how much grazing land is available within the watershed. Land use information by watershed is published in the TMDL of Echo Reservoir and can be found in Appendix C. Similarly, to reduce phosphorus loading from private land grazing in Chalk Creek Watershed using stream fencing, we need to know how much length of stream can be fenced. This information was obtained from a map that shows land use distribution within the Echo Reservoir Watershed. To estimate how much fencing could be implemented in each watershed under consideration, the length of stream in that watershed was measured off the map. This map can be found in Appendix D of this document.

As shown in Table 1, the Echo Reservoir Watershed was subdivided into three parts for purposes of phosphorus load allocation. The parts are:

- Chalk Creek Watershed: consisting of only Chalk Creek.
- Weber River below Wanship Reservoir: consisting of Weber River below Wanship Reservoir Watershed, Silver Creek Watershed and Weber River below Silver Creek Watershed.
- Weber River above Wanship Reservoir: consisting of Upper Weber River Watershed, Beaver Creek Watershed and Weber River below Beaver Creek Watershed.

Likewise our analysis and selection of BMPs will follow the same classification.

At any given location in the Echo River Watershed, once we know the reduction required of a given source of phosphorus loading and the appropriate BMPs that should be considered, we can then set up an optimization problem to identify a set of BMPs that should be selected under certain constraints. To facilitate the computation, the solver function in Excel was used to solve the problem. The following generalized optimization model was used.

**Equation 1: Optimization model for BMP selection.**

$$
\begin{aligned}
& Min \sum_{i}^{n} \left( P_{r,i} * U_{c,i} \right) \\
& S.T: \\
& P_{r,i} = E_i * A_{r,i}; \\
& \sum_{i}^{n} \left( P_{r,i} \right) \geq P_{R,i}; \\
& \sum_{i}^{n} \left( A_{r,i} \right) \leq A_{R,i}; \\
& P_{r,i} \geq 0; \\
& A_{r,i} \geq 0;
\end{aligned}
$$

Where: $P_{r,i}$ = The amount of phosphorus removed by BMP(i), in kg/yr; (Computed)

$U_{c,i}$ = The unit cost of BMP (i), \$/kg; (Given on Table 2)[2]

$E_i$ = The removal efficiency of BMP (i), kg/km$^2$; (Given on Table 2)

$A_{r,i}$ = Area used in the removal of phosphorus, km$^2$ (Computed)

$P_R$ = The required phosphorus reduction, kg/yr (Given in Table 1)

$A_R$ = The available area for BMP application, km$^2$ (Given in Appendix C)

[2] In doing our analysis, we have used metric units. Table 2 with metric units has been reproduced in Appendix E.

## 6. Results and Discussion

Based on the optimization model presented in the methodology, selection of BMPs was accomplished considering three sources of phosphorus loading and three main location of the sub watershed. Results are presented in two ways: by Source of phosphorus loading and by Location.

### 6.1.Analysis by Source of phosphorus loading

- **Land applied manure:** Table 5 shows the selection of BMP6 , BMP8 and BMP9 and the cost of reduction of phosphorus loading for each location caused by land applied manure. For example if we want to reduce 754 kg/yr of phosphorus loading at the Weber River below Wanship we need to spend $126,266.67/yr to implement Agricultural Nutrient Management (BMP 9) on an area of 17.24 Km$^2$. In this case the reduction achieved is 753.6 Kg/yr of phosphorus loading which is almost equal to the required reduction. However, for Weber River above Wanship the required reduction of 2,848 kg/yr could not be achieved even after using all the appropriate BMPs applied on all the available area and in some cases stream length. This is one case where installing treatment plant can be feasible after proper review and study.

**Table 5: BMP selection for reducing phosphorus loading from land applied manure.**

| Subwatershed | Existing Total Watershed Load(kg/yr) | Required Reduction to achieve TMDL(kg/yr) | BMP6 : Grass filter strips | | | BMP8 : Conservation tillage | | | BMP9: Agricultural nutrient management | | | Total Cost($/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Required Area (Km$^2$) | P removal (kg/yr) | Cost( $/yr) | Required Area (Km2) | P removal (kg/yr) | Cost( $/yr) | Required Area (Km2) | P removal (kg/yr) | Cost( $/yr) | |
| Chalk Creek | 961 | 769 | 0.00 | - | - | 4.31 | 86.87 | 29,303.28 | 15.60 | 681.93 | 114,257.57 | 143,560.86 |
| Weber River Below Wanship | 942 | 754 | 0.00 | - | - | - | - | - | 17.24 | 753.60 | 126,266.67 | 126,266.67 |
| Weber River Above Wanship | 3,560 | 2848 | 2.60 | 373.02 | 153,782.57 | 24.50 | 494.30 | 166,729.41 | 24.50 | 1,070.97 | 179,442.99 | 499,954.97 |
| | | | | | | | | | | | Total | 769,782.51 |

- **Private land grazing:** Table 6 shows the selection of Grazing Land Protection (BMP2) and the cost of reduction of phosphorus loading for each location caused by private land grazing. For example if we want to reduce 155 kg/yr of phosphorus loading at the Weber River below Wanship we need to spend $ 36,905.38/yr to implement of Grazing Land Protection on an area of 7.13 $Km^2$ . In this also, the required reduction has been achieved.

**Table 6: BMP selection for reducing phosphorus loading from private land grazing.**

| Sub watershed | Existing Total Watershed Load(kg/yr) | Required Reduction to achieve TMDL(kg/yr) | BMP2 : Grazing land protection | | |
|---|---|---|---|---|---|
| | | | Grazing Area ($Km^2$) | P removal (kg/yr) | Cost( $/yr) |
| Chalk Creek | 3535 | 354 | 16.26 | 353.50 | 84,168.08 |
| Weber River Below Wanship | 1550 | 155 | 7.13 | 155.00 | 36,905.38 |
| Weber River Above Wanship | 3,718 | 372 | 17.10 | 371.80 | 88,525.30 |
| | | | | **Total** | **209,598.76** |

- **Diffuse Runoff:** Table 7 shows the selection of BMP4 and the cost of reduction of phosphorus loading for each location caused by diffuse runoff. For example if we want to reduce 549.3 Kg/yr of phosphorus loading at the Weber River below Wanship we need to spend $ 8,476.99/yr to implement Stream Bank Stabilization on a stream length of 2.64 km to achieve the required phosphorus load reduction.

**Table 7: BMP selection for reducing phosphorus loading from diffuse runoff.**

| Sub watershed | Existing Total Watershed Load(kg/yr) | Required Reduction to achieve TMDL(kg/yr) | BMP4 : Stream bank stabilization | | |
|---|---|---|---|---|---|
| | | | Length of stream for bank stabilization(km) | P removal (kg/yr) | Cost( $/yr) |
| Chalk Creek | 6539 | 915 | 4.39 | 915.46 | 14,127.71 |
| Weber River Below Wanship | 5493 | 549 | 2.64 | 549.30 | 8,476.99 |
| Weber River Above Wanship | 13,517 | 1352 | 6.49 | 1,351.70 | 20,859.92 |
| | | | | **Total** | **43,464.62** |

## 6.2.Analysis by Location

Table 8 shows the percentage reduction of phosphorus by location and source of phosphorus loading. From Table 8, we see that to achieve the required phosphorus reduction from land applied manure at Chalk Creek, both BMP8 and BMP9 can be used. BMP8 achieves 11.3% while BMP9 achieves 88.7% of the required phosphorus loading reduction at Chalk Creek. Also to reduce phosphorus loading related with private land and diffuse runoff, it is necessary to apply BMP 2 and BMP4 respectively.

**Table 8: Percentage of reduction of phosphorus loading by location and source of phosphorus.**

| Sub watershed | % P Reduction - Land applied manure | | | | % P Reduction - Private Land Grazing | % P Reduction - Diffuse Runoff |
|---|---|---|---|---|---|---|
| | BMP6 | BMP8 | BMP9 | Total | BMP2 | BMP4 |
| Chalk Creek | 0.0 | 11.3 | 88.7 | 100.0 | 100.0 | 100.0 |
| Weber River below Wanship | 0.0 | 0.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Weber River above Wanship | 13.1 | 17.4 | 37.6 | 68.1 | 100.0 | 100.0 |

For the Weber River below Wanship, we need to implement BMP9, BMP2 and BMP4 in order to reduce 100 % of the phosphorus load that come from land applied manure, private land and diffuse runoff respectively.

For the Weber River above Wanship, we select to apply BMP6, BMP8 and BMP9 to reduce the phosphorus load that come from land applied manure. Even though we use three BMP, it is not possible to reduce 100% of P loading. We only reduce 68.1% of the phosphorus load that come from land applied manure. For private land grazing and diffuse runoff, we use BMP2 and BMP4 respectively  to reduce 100% phosphorus load.

Table 9 shows that total reduction of phosphorus to achieve the TMDL requirement at Echo Reservoir is 8 067.16 Kg/year from three locations within the Echo Reservoir Watershed. Our analysis has shown that using different BMPs, we can reduce 88.72 % (7,157 kg/year) of phosphorus loading with a total cost of $ 1,022,845.89.

**Table 9: Summary of proposed BMPs, the reduction of phosphorus loading achieved, and costs.**

| Subwatershed | Existing Total Watershed Load(kg/yr) | Required Reduction to achieve TMDL(kg/yr) | BMP2 | BMP4 | BMP6 | BMP8 | BMP9 | Total P Reduction (kg/yr) | Total Cost ($) |
|---|---|---|---|---|---|---|---|---|---|
| Chalk Creek | 11,035.00 | 2038 | 353.50 | 915.46 | - | 86.87 | 681.93 | 2,037.76 | 241,856.65 |
| Weber River Below Wanship | 7,985.00 | 1458 | 155.00 | 549.30 | - | - | 753.60 | 1,457.90 | 171,649.05 |
| Weber River Above Wanship | 20,795.00 | 4572 | 371.80 | 1,351.70 | 373.02 | 494.30 | 1,070.97 | 3,661.79 | 609,340.19 |
| **Total** | **39,815.00** | **8,067.16** | **880.30** | **2,816.46** | **373.02** | **581.17** | **2,506.50** | **7,157.45** | **1,022,845.89** |

Figure 2 shows the magnitude of reduction of each BMP for the three locations analyzed. We can see that BMP 4 and BMP 9 are the most suitable in the three locations.

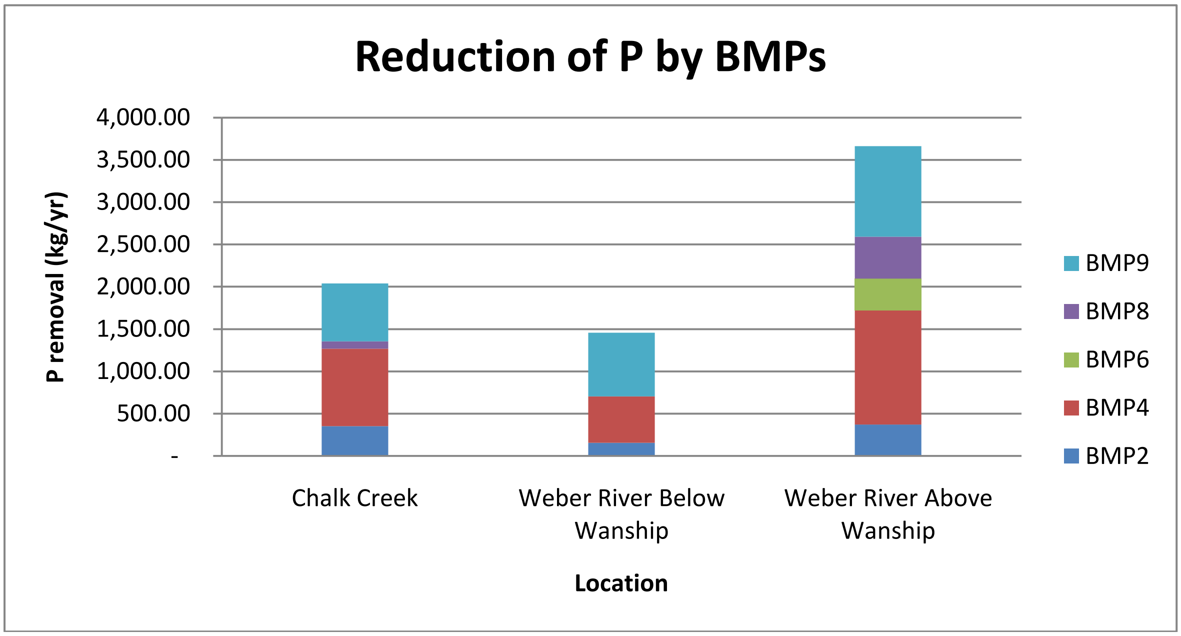


**Figure 2: Summary of proposed BMPs and their associated phosphorus reduction by location.**

In Figure 3 bars represent the total reduction of P loading using BMPs, and the line represents the required reduction of phosphorus that should be achieved at each location. Results of this analysis show that for Weber River above Wanship, the required phosphorus load reduction is not completely achieved. Thus it may be necessary to explore other more efficient BMPs or consider installing treatment plant.

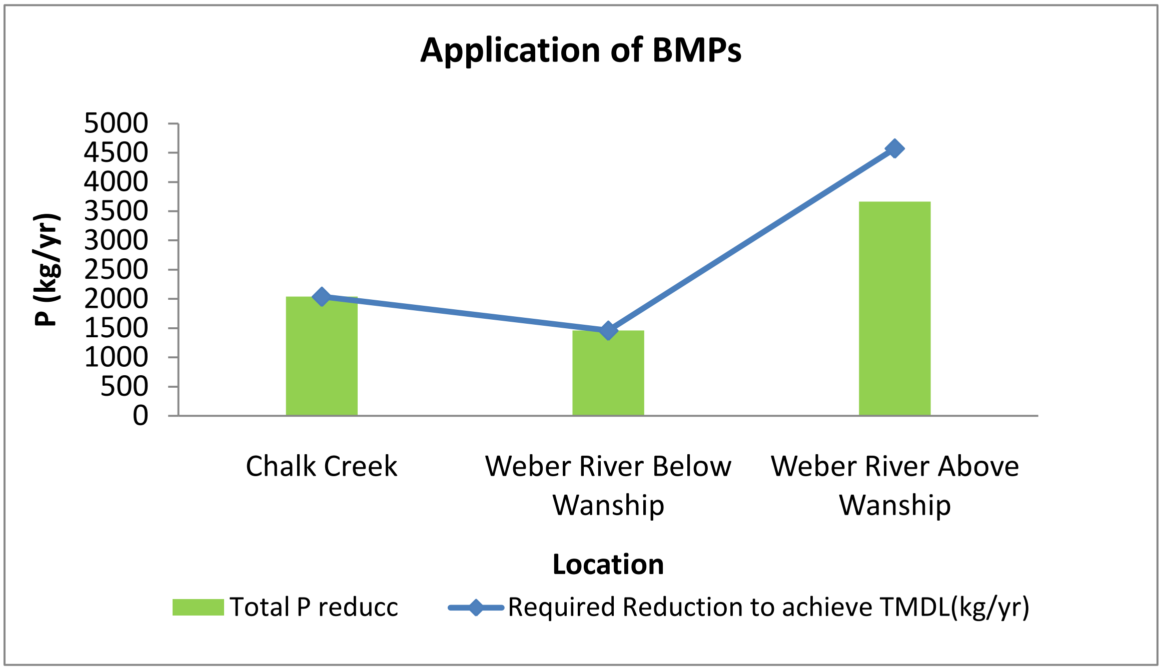


**Figure 3: Comparison of phosphorous reduction achieved using proposed BMPs and the required phosphorus reduction as per TMDL of Echo Reservoir by location.**

## 7. Conclusion

- ✓ Several Best Management Practices were identified to reduce phosphorus loading at the Echo Reservoir Watershed. To select the best combination of BMPs, a simple optimization model was formulated. The objective function of this model was minimizing cost of reduction of phosphorus loading subject to available area for application of BMPs.

- ✓ Results of the model show that using BMP2, BMP4, BMP6, BMP8, BMP9 at the three locations of the Echo Reservoir Watershed can reduce 88.72 % of the required phosphorus reduction to achieve TMDL at Echo Reservoir at a total cost of $ 1,022,845.89.

- ✓ Our analysis on Weber River above Wanship shows that the proposed BMPs do not achieve the required phosphorus load reduction.

## 8. Recommendations

In this study, the analysis was mainly based on the cost and definitions of BMPs provided in Tables 2 and 3 respectively. As discussed above the cost information was based on Potomac River Watershed and is not representative of the conditions at the Echo Reservoir Watershed. Therefore it is recommendable that the BMPs should be specifically defined and estimated for each source and location in the watershed under study. This could improve the cost implication of each BMP and could give better results for estimating phosphorus reduction.

Most BMPs are applied on an area or in some cases along streams. In our analysis, we have satisfied our needs by using areal and stream length estimates from available information. It would improve the results of this report if more accurate information could be acquired and used.

Since our analysis has shown that the required phosphorus reduction at Weber River above Wanship was not completely achieved, it is recommended to explore other efficient BMPs or consider installing a treatment plant which can be installed immediately above the Echo Reservoir. Further study needs to be conducted to decide on the capacity and efficiency of phosphorus removal required for such a treatment plant.

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# Appendix A

## Echo Reservoir TMDL

| | |
|---|---|
| **Waterbody ID** | UT-L-16020101-001 |
| **Location** | Summit County, Utah |
| **Pollutants of Concern** | Dissolved Oxygen, Total Phosphorus |
| **Impaired Beneficial Uses** | Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain. |
| **Loading Assessment** | • More than 50% of water column < 4 mg/l dissolved oxygen in Echo Reservoir above Dam.<br>• Percent of in-lake total phosphorus concentrations exceeding 0.025 mg/l ranging from 25% - 100% |
| **Water Quality Targets/Endpoints** | • Target Load of 19,800 kg/yr total phosphorus from all tributary sources to Echo Reservoir.<br>• A shift away from blue-green algal dominance.<br>• TSI values for Total Phosphorus, Chlorophyll A, and Secchi depth not to exceed 50. |
| **Implementation Strategy** | • Reduce Point Source loads through application of BATs<br>• Implement Nonpoint Source BMPs<br>  ○ CNMPs on all AFO facilities in study area.<br>  ○ Remove livestock access to water and provide off-site watering sources along selected stream corridors.<br>  ○ Implement riparian buffer strips on degraded stream segments and along other selected stream corridors. |
| This document is identified as a TMDL for Echo Reservoir and is submitted under §303d of the Clean Water Act to U.S. EPA for review and approval. | |

# Appendix B

| Sub-watershed | Name | Description | Total Area ($km^2$) |
|---|---|---|---|
| 1 | Upper Weber River | From headwaters of Weber River down to the confluence with Beaver Creek. | 456 |
| 2 | Beaver Creek | From headwaters of Beaver Creek down to the confluence with the Upper Weber River. | 234 |
| 3 | Weber River Below Beaver Creek | Weber River from confluence with Beaver Creek down to the inlet of Wanship Reservoir. | 71 |
| 4 | Wanship Reservoir | All land that drains directly into Wanship Reservoir, including all land below the reservoir inlet and above the reservoir outlet. | 103 |
| 5 | Weber River Below Wanship Reservoir | Weber River from Wanship Reservoir to the confluence with Silver Creek. | 12 |
| 6 | Silver Creek | From headwaters of Silver Creek to the confluence with the Weber River. | 122 |
| 7 | Weber River Below Silver Creek | Weber River from confluence with Silver Creek to the inlet of Echo Reservoir. | 134 |
| 8 | Chalk Creek | From headwaters of Chalk Creek down to Echo Reservoir. | 646 |
| 9 | Echo Reservoir | All land that drains directly into Echo Reservoir, including all land below the reservoir inlet and above the reservoir outlet. | 101 |

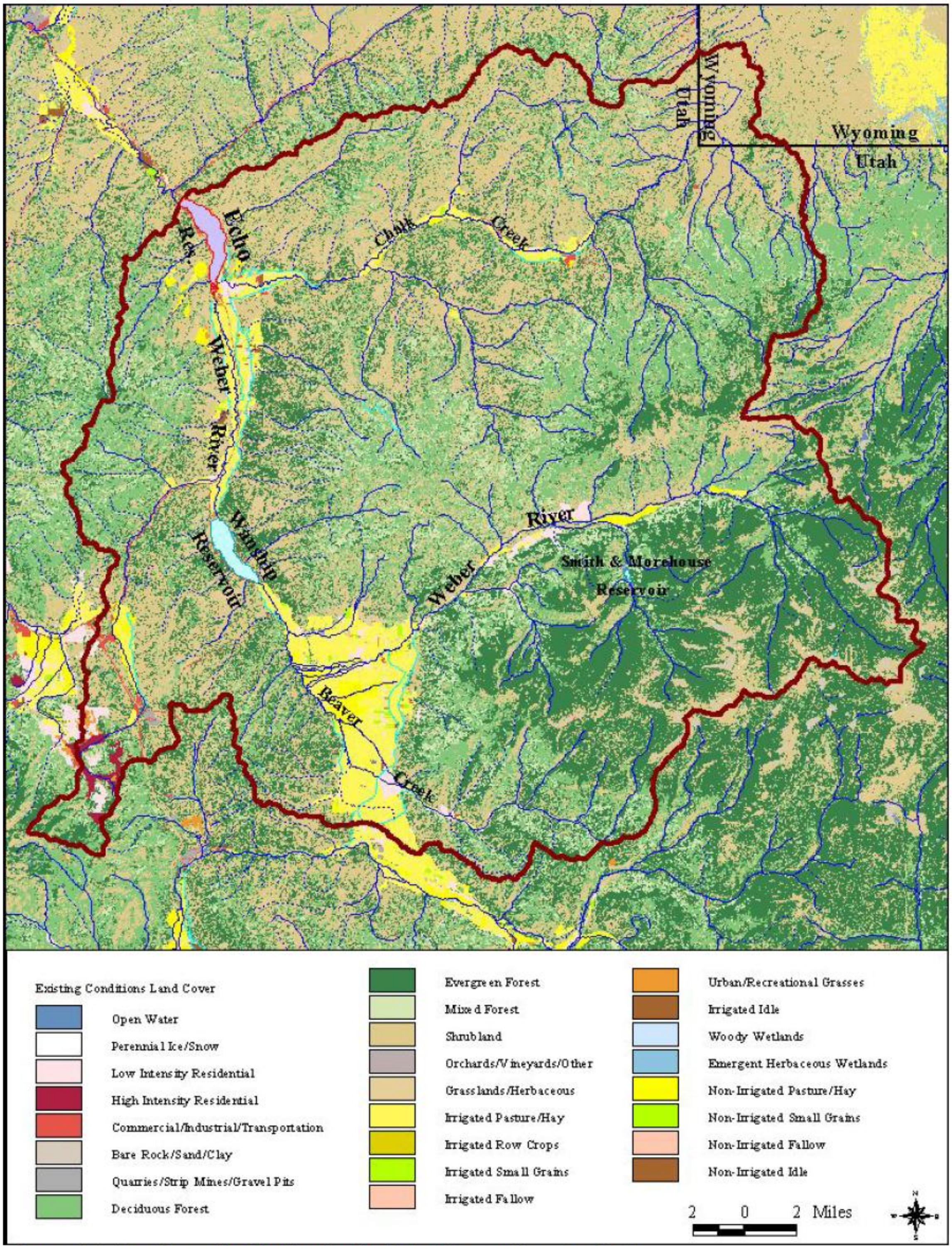
# Appendix C

| Land Use Category | Area | | |
|---|---|---|---|
| | Acres | Square Kilometers | Percent |
| **Upper Weber River Subwatershed** | | | |
| Urban/Residential/Transportation | 1,558 | 6.3 | 1.4 |
| Forest Land | 79,190 | 320.5 | 70.3 |
| Range Land | 26,492 | 107.2 | 23.5 |
| Agriculture | 2,963 | 12.0 | 2.6 |
| Wetlands | 30 | 0.1 | 0.0 |
| Barren | 2,167 | 8.8 | 1.9 |
| Water | 196 | 0.8 | 0.2 |
| **Total for Subwatershed** | 112,595 | 455.7 | 100 |
| **Beaver Creek Subwatershed** | | | |
| Urban/Residential/Transportation | 1,233 | 5.0 | 2.1 |
| Forest Land | 34,268 | 138.7 | 59.3 |
| Range Land | 12,141 | 49.1 | 21.0 |
| Agriculture | 9,991 | 40.4 | 17.3 |
| Wetlands | 12 | 0.0 | 0.0 |
| Barren | 172 | 0.7 | 0.3 |
| Water | 9 | 0.0 | 0.0 |
| **Total for Subwatershed** | 57,826 | 234.0 | 100 |
| **Weber River Below Beaver Creek Subwatershed** | | | |
| Urban/Residential/Transportation | 404 | 1.6 | 2.3 |
| Forest Land | 7,127 | 28.8 | 40.8 |
| Range Land | 5,645 | 22.8 | 32.3 |
| Agriculture | 4,292 | 17.4 | 24.5 |
| Wetlands | 0 | 0.0 | 0.0 |
| Barren | 19 | 0.1 | 0.1 |
| Water | 0 | 0.0 | 0.0 |
| **Total for Subwatershed** | 17,489 | 70.8 | 100 |
| **Wanship Reservoir Subwatershed** | | | |
| Urban/Residential/Transportation | 160 | 0.6 | 0.6 |
| Forest Land | 11,915 | 48.2 | 46.7 |
| Range Land | 12,437 | 50.3 | 48.8 |
| Agriculture | 35 | 0.1 | 0.1 |
| Wetlands | 56 | 0.2 | 0.2 |
| Barren | 36 | 0.1 | 0.1 |
| Water | 872 | 3.5 | 3.4 |
| **Total for Subwatershed** | 25,512 | 103.2 | 100 |
| **Weber River Below Wanship Reservoir Subwatershed** | | | |
| Urban/Residential/Transportation | 73 | 0.3 | 2.6 |
| Forest Land | 1,259 | 5.1 | 44.0 |
| Range Land | 1,124 | 4.5 | 39.3 |
| Agriculture | 401 | 1.6 | 14.0 |
| Wetlands | 1 | 0.0 | 0.0 |
| Barren | 0 | 0.0 | 0.0 |
| Water | 0 | 0.0 | 0.0 |
| **Total for Subwatershed** | 2,859 | 11.6 | 100 |

## Appendix C (Cont'd)

| | Area | | |
|---|---|---|---|
| **Land Use Category** | **Acres** | **Square Kilometers** | **Percent** |
| **Silver Creek Subwatershed** | | | |
| Urban/Residential/Transportation | 2798 | 11.3 | 9.3 |
| Forest Land | 16,121 | 65.2 | 53.4 |
| Range Land | 9,626 | 39.0 | 31.9 |
| Agriculture | 1,457 | 5.9 | 4.8 |
| Wetlands | 2 | 0.0 | 0.0 |
| Barren | 165 | 0.7 | 0.5 |
| Water | 5 | 0.0 | 0.0 |
| **Total for Subwatershed** | 30,174 | 122.1 | 100 |
| **Weber River Below Silver Creek Subwatershed** | | | |
| Urban/Residential/Transportation | 654 | 2.6 | 2.0 |
| Forest Land | 15,318 | 62.0 | 46.4 |
| Range Land | 12,808 | 51.8 | 38.8 |
| Agriculture | 4,181 | 16.9 | 12.7 |
| Wetlands | 12 | 0.0 | 0.0 |
| Barren | 48 | 0.2 | 0.1 |
| Water | 0 | 0.0 | 0.0 |
| **Total for Subwatershed** | 33,021 | 133.6 | 100 |
| **Chalk Creek Subwatershed** | | | |
| Urban/Residential/Transportation | 666 | 2.7 | 0.4 |
| Forest Land | 77,817 | 314.9 | 48.7 |
| Range Land | 77,053 | 311.8 | 48.3 |
| Agriculture | 3852 | 15.6 | 2.4 |
| Wetlands | 22 | 0.1 | 0.0 |
| Barren | 181 | 0.7 | 0.1 |
| Water | 39 | 0.2 | 0.0 |
| **Total for Subwatershed** | 159,629 | 646.0 | 100 |
| **Echo Reservoir Subwatershed** | | | |
| Urban/Residential/Transportation | 174 | 0.7 | 0.7 |
| Forest Land | 9,890 | 40.0 | 39.5 |
| Range Land | 12,833 | 51.9 | 51.3 |
| Agriculture | 851 | 3.4 | 3.4 |
| Wetlands | 401 | 1.6 | 1.6 |
| Barren | 47 | 0.2 | 0.2 |
| Water | 837 | 3.4 | 3.3 |
| **Total for Subwatershed** | 25,032 | 101.3 | 100 |
| **All Subwatersheds Combined** | | | |
| Urban/Residential/Transportation | 7,720 | 31.2 | 1.7 |
| Forest Land | 252,905 | 1,023.5 | 54.5 |
| Range Land | 170,159 | 688.6 | 36.7 |
| Agriculture | 28,024 | 113.4 | 6.0 |
| Wetlands | 536 | 2.2 | 0.1 |
| Barren | 2,836 | 11.5 | 0.6 |
| Water | 1,958 | 7.9 | 0.4 |
| **Total of all Subwatersheds** | 464,138 | 1,878.3 | 100 |

# Appendix D



Wyoming
Utah
Wyoming
Utah
Echo
Res.
Chalk
Creek
Weber
River
Wanship
Reservoir
River
Weber
Smith & Morehouse
Reservoir
Beaver
Creek
Existing Conditions Land Cover
Open Water
Perennial Ice/Snow
Low Intensity Residential
High Intensity Residential
Commercial/Industrial/Transportation
Bare Rock/Sand/Clay
Quarries/Strip Mines/Gravel Pits
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrubland
Orchards/Vineyards/Other
Grasslands/Herbaceous
Irrigated Pasture/Hay
Irrigated Row Crops
Irrigated Small Grains
Irrigated Fallow
Urban/Recreational Grasses
Irrigated Idle
Woody Wetlands
Emergent Herbaceous Wetlands
Non-Irrigated Pasture/Hay
Non-Irrigated Small Grains
Non-Irrigated Fallow
Non-Irrigated Idle
2 0 2 Miles

# Appendix E

| BMP | English Units | Metric Units | P Reduction (lb/unit) | Cost($/lb) | P Reduction (kg/unit) | Cost ($/kg) |
|---|---|---|---|---|---|---|
| **Land retirement** | acre | $Km^2$ | 1.65 | 3342.00 | 184.94 | 7367.85 |
| **Grazing land protection** | acre | $Km^2$ | 0.19 | 108.00 | 21.74 | 238.10 |
| **Stream fencing** | linear foot | Km | 0.02 | 623.00 | 23.81 | 1373.48 |
| **Stream bank stabilization** | linear foot | Km | 0.14 | 7.00 | 208.34 | 15.43 |
| **Cover crops** | acre | $Km^2$ | 0.39 | 306.00 | 43.71 | 674.61 |
| **Grass filter strips** | acre | $Km^2$ | 1.28 | 187.00 | 143.47 | 412.26 |
| **Animal waste facility** | system | system | 241.84 | 331.00 | 27106.66 | 729.73 |
| **Conservation tillage** | acre | $Km^2$ | 0.18 | 153.00 | 20.18 | 337.31 |
| **Agricultural nutrient management** | acre | $Km^2$ | 0.39 | 76.00 | 43.71 | 167.55 |
| **Sprinkler irrigation** | acre | $Km^2$ | 26.00 | 58.00 | 2914.21 | 127.87 |