6. PHOSPHORUS SOURCE IDENTIFICATION AND LOAD ANALYSIS

This section discusses pollutant sources that contribute to the impairment of East Canyon Reservoir. The DO impairment in East Canyon Creek is caused by poor physical stream conditions that promote high densities of rooted aquatic plants (macrophytes). The lack of shade provided by large, mature woody riparian vegetation along the majority of the stream channel allows excessive light and heat inputs to support these dense plant beds, especially in low gradient, depositional areas such as at the Blackhawk and Bear Hollow monitoring sites.

East Canyon Reservoir has historically been co-limited by nitrogen and phosphorus; recent reductions in phosphorus have pushed the system to stronger phosphorus limitation. This section focuses exclusively on phosphorus because control of blue-green algae, required to support the Reservoir's beneficial uses, can only be achieved through phosphorus control.

6.1 MAJOR SOURCES OF NUTRIENT LOADING TO EAST CANYON RESERVOIR

The East Canyon Reservoir Watershed encompasses 92,498 acres in Summit and Morgan counties. Over 96% of the watershed area is privately owned. Forested and meadow lands are the largest land cover type in the watershed with over 65,668 acres (71%).

East Canyon Reservoir is fed by East Canyon Creek and its contributing 145 square mile watershed. With an average volume of over 41,000 acre-feet per year flowing into the reservoir and the average active storage volume of the reservoir at 48,100 acre-feet, a significant proportion of nutrients present in the reservoir at a given time are derived from current upstream land uses and human activities. Anoxic conditions during the summer at the sediment-water interface result in the release of iron-bound phosphorus from reservoir sediments that becomes available to algae during the fall turnover period. The area directly draining into the reservoir (as opposed to inflow from East Canyon Creek) includes an area of 20,163 acres, or 22% of the watershed. Identified sources of phosphorus to East Canyon Reservoir are as follows:

- ECWRF discharge
- Forest land management, including ski area management
- Pasturing of livestock
- Runoff from agricultural lands
- Stormwater runoff, including urban/suburban areas, golf courses, and active construction sites
- Onsite wastewater treatment systems (septic systems)
- Stream erosion and reservoir shoreline erosion
- Atmospheric sources, e.g. dust
- Natural background sources including phosphatic shales lithology and wildlife
- Reservoir bottom sediments

6.1.1 POINT SOURCES

The only permitted point source discharge located in the East Canyon Reservoir watershed is the ECWRF operated by the Snyderville Basin Water Reclamation District (SBWRD). The ECWRF is located near East Canyon Creek just upstream of Jeremy Ranch. The treatment plant discharges its treated effluent to East Canyon Creek and operates under Utah Pollution Discharge Elimination System (UPDES) permit #UT0020001. The population of the watershed increases in the winter due to crowds attracted to several ski resorts in the area. Several annual and one-time special events lead to additional, temporary increases in the normal, yearly winter resort population. These include ski competitions and the Sundance Film

Festival. The permit for the ECWRF reflects this seasonality. A total phosphorus concentration not to exceed 0.1 mg/L applies to the months of July, August, and September. This concentration is effective until April 29, 2010. In addition, the permit requires limits to the annual total phosphorus load from the system to 1,462 lbs/year. These effluent limitations were originally developed to protect East Canyon Creek by imposing a phosphorous limitation during the summer growing season. However, the resulting permit also provides the system with flexibility, if necessary, to discharge more during peak ski season and during special events and less during non-tourist times of the year.

Upgrades to the ECWRF in September 2002 involved adding a chemical phosphorus reduction process to the plant that became fully effective in July 2003. The process mixes secondary effluent with alum (aluminum sulfate) and a polymer in solids-contact clarifiers, and then filters the liquid through a constant-backwash sand filter. Effluent from the treatment system meets tertiary treatment standards, the highest effluent quality attainable with currently available technology. For water years 2003 through 2007 the average total phosphorus concentration from ECWRF was 0.12 mg/L and 0.024 mg/L for orthophosphate. Phosphorus concentrations range from nondetectable (< 0.02 mg/L) to 2.8 mg/L (5/23/2003). The median total phosphorus concentration of ECWRF effluent is 0.06 mg/L. The treatment plant consistently meets its summer effluent permit standard of 0.1 mg/L. A summary of total phosphorus concentrations in ECWRF effluent is shown in Figure 6.1.

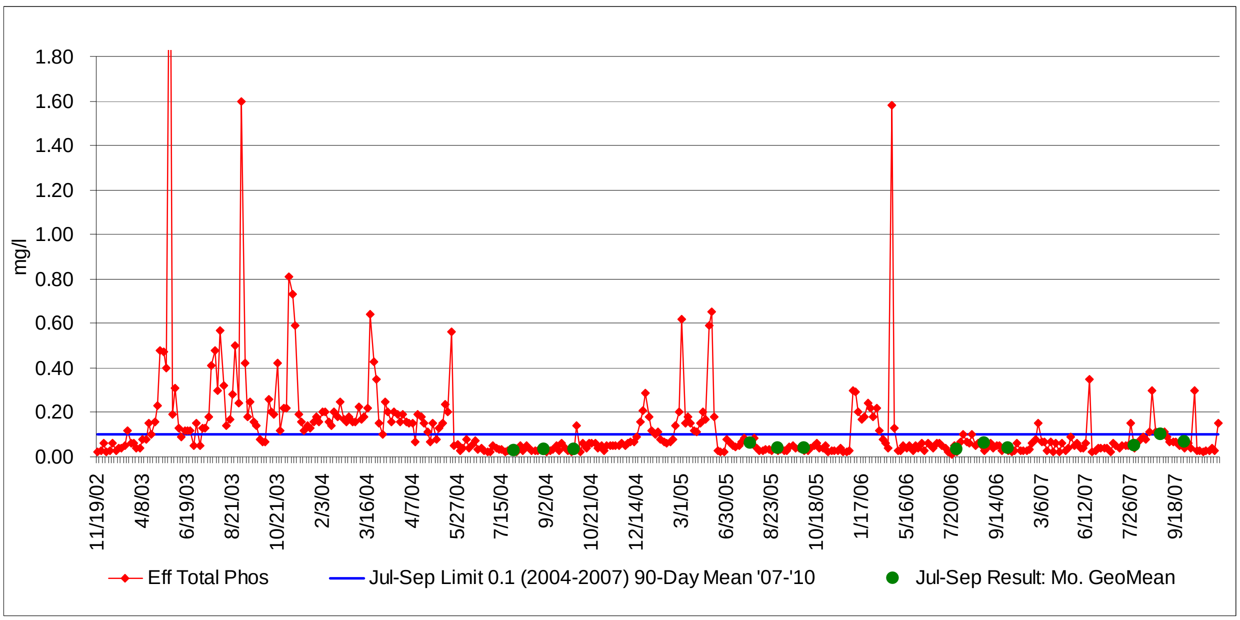

Figure 6.1 Total phosphorus concentrations in ECWRF effluent during water years 2002–2007.

Discharge volume from ECWRF has ranged from a minimum of 1.33 MGD to 6.06 MGD during the peak tourist ski season. Average effluent volume has been 2.61 MGD during water years 2003–2007. ECWRF effluent is sampled and analyzed on a weekly basis. Average monthly effluent concentrations and discharge were used to build a daily load estimate for the ECWRF. Daily loads were summarized by water year and averaged to estimate an annual average total phosphorus load to East Canyon Creek from ECWRF.

6.1.2 NONPOINT SOURCES

A number of nonpoint pollutant sources in the watershed contribute to the impairment of East Canyon Reservoir. For the purposes of this characterization, nonpoint sources in the watershed were grouped into five major categories: urban/suburban development, agriculture, recreation, natural background and finally, other nonpoint sources. The corresponding land-use categories reported by BIO-WEST (2008) are given for each land use in the sections that follow. All of these sources contribute to the impairment in the watershed. Land uses, including agricultural production and urban development, have increased the amount of sediment and nutrient loading into surface waters. Specific sources include excessive fertilizer applications on turf and agricultural lands, construction sites that don't implement Storm Water Pollution Prevention Plans (SWPPPs), and streambank erosion. Natural events can also produce high sediment and nutrient loads to the reservoir such as large floods.

6.1.2.1 Urban/Suburban Nonpoint Sources

The East Canyon Reservoir watershed had an estimated population of 68,173 in 2005. Summit County has had an explosive population increase of nearly 92% since the 1990 census. This population growth is more than double the average growth rate for the State of Utah during the same period. Almost 70% of the population growth has occurred in unincorporated areas of Summit County. Based on past trends, population growth in the watershed, specifically in Summit County, is likely to continue. A small proportion of the lower watershed occurs in Morgan County, and contains a population of 8,525 or 12.5% of the watershed's total population. The 29% population growth rate in Morgan County is more in line with the Utah average.

The upper East Canyon watershed contains urban areas, suburban neighborhoods, and small ranchettes. Sediment and nutrient loads from rural subdivisions originate from roadway and impervious surface runoff, over-watering of landscaped areas and pet wastes. In the Snyderville Basin, developable lands in the basin are restricted to 1 unit per 20-acre parcels. The unincorporated areas of Snyderville Basin in Summit County are under the jurisdiction of the Snyderville Basin General Plan (Snyderville Basin Planning Commission 2002). Specific sources significant to the attainment of water quality goals for the East Canyon Reservoir watershed are discussed in the following sections.

6.1.2.1.1 Municipal Stormwater Runoff

Stormwater discharges from urban areas consist of concentrated flows which accumulate from streets, parking areas, rooftops, and other impervious surfaces. Constituents transported during storm events can include oil and grease from vehicles, sediment, nutrients, and organic matter such as litter, yard clippings and pet wastes. Discharges from Municipal separate Storm Sewer Systems (MS4s) are permitted under the Utah General Stormwater Permit for Small Dischargers issued on December 9, 2002. Under the General Permit, a municipality is authorized to discharge stormwater to waters of the State as long as the discharge does not impair the receiving waterbody.

Summit County has developed an ordinance (Summit County Ordinance No. 519) to protect water resources from illicit discharges within the county boundaries. Park City has the largest amount of high density development in the watershed, with a total average density of 781.4 residents per square mile. Park City Municipal Corporation (PCMC) has actively engaged in stormwater pollution prevention activities including the education and enforcement of the construction, golf, and ski industries and the implementation and management of BMPs for the protection of surface water resources. According to Park City's General Plan (Park City 2000), existing natural hydrologic features such as wetlands, depressions, and drainages will be managed to protect the hydrologic conditions in the watershed.

PCMC has exceeded their environmental goals for multiple years and continues to expand their efforts to control nonpoint source nutrients and sediment (PCMC 2007). Their projects include requiring all service stations to have an oil/water separator for their stormwater runoff, installing 100 "No Dumping Drains to Watershed" signs on drains throughout the county, adding silt traps to stormwater accumulation structures, and the development and maintenance of sediment detention basins. They have placed signs throughout the watershed detailing proper management of dog waste and stormwater and publish an Environmental Information Handbook, a Residential Stormwater Brochure, and information on invasive weed species and Xeriscape gardening.

6.1.2.1.2 Onsite Wastewater Treatment Systems (Septic Systems)

Most of the urban and residential development in the watershed is located in the Park City, Kimball Junction and Jeremy Ranch areas where there is sewer system access. Septic tanks in the watershed are allowed in areas where central sewer systems are not feasible or present. The majority of these systems are found in the Silver Creek subbasin, which flows south into East Canyon Creek. Onsite septic systems have the potential to contribute nutrient loads to surface waters via leachfield contamination of groundwater that recharges streams, or directly when leachfields fail. Septic system leachfields can protect ground and surface waters from nutrient and bacterial contamination if they are constructed and maintained properly.

6.1.2.1.3 Active Construction

PCMC conducts BMP and environmental ordinance training sessions and workshops for local contractors and enforces these regulations during construction. PCMC requires that all construction activities must adhere to environmental ordinances and mitigation requirements. A signed agreement to comply with environmental ordinances is required for all projects that need a building permit. A "Stop Work" order is issued if stormwater BMPs are not implemented. A contractor must resolve the issue in a timely manner or the building permit is revoked (PCMC 2007).

6.1.2.2 Agricultural Nonpoint Sources

Approximately 2,200 acres of agricultural lands are present in the watershed. Primary sources of pollutants associated with agriculture consist of sediment and nutrient loads from irrigation, cropping, and pasturing. The following influences the generation and transport of pollutants from agricultural nonpoint sources:

- The ecological health of riparian areas
- Overland flow from runoff and snowmelt
- Irrigation practices
- Pasture and rangeland management
- Fertilizer application
- Consumptive water use

6.1.2.2.1 Animal Feeding Operations

Feedlots and corrals, hereinafter referred to as Animal Feeding Operations (AFOs), pose risks to water quality from manure and other animal wastes that can contribute nutrients and sediments directly to nearby surface waters such as streams and canals. At present, there are several AFOs located in the watershed, most of which are associated with horse properties.

Sediment and nutrient loads from AFOs can be controlled through the implementation of BMPs and Comprehensive Nutrient Management Plans that address animal waste and grazing management.

6.1.2.2.2 Irrigation Return Flow

Irrigation water applied to pasture and hay lands in excess of the soil infiltration rate will wash soil and nutrients off the field and ultimately into a receiving water. Irrigation return flows are usually enriched with organic matter, sediment, and nutrients.

Over-irrigation of pasture and hayland will also raise the water table and lead to changes in the mobility of phosphorus in soils. Phosphorus has been observed to move more easily through soils that are consistently waterlogged because the majority of the iron present in these soils is reduced and sorption potential is decreased (Sharpley et al. 1995). Waterlogged soils are also prone to the loss and transport of fine, lightweight soil particles such as silt and clay to receiving waters. These fine particles represent the primary phosphorus sorption sites in the soil. These particles carry a significant amount of phosphorus with them when they are removed and leave the remaining soil deficient in phosphorus holding capacity (Hedley et al. 1995).

6.1.2.2.3 Pasture Land

Livestock, including horses, sheep, cattle and other grazing animals are located on ranch lands and pastures in the watershed. The majority of grazing animals are found along and adjacent to streams, resulting in a greater potential for direct transport of manure into surface waters. The phosphorus contained in manure is in a highly soluble, readily bioavailable form. A small portion of the available phosphorus in plant material is used by grazing animals for growth and maintenance, whereas 60% to 95% of phosphorus intake is excreted into the environment as manure (Magdoff et al. 1997). Because of the high solubility of phosphorus in manure, loading and transport from a field with livestock manure on it can exceed loads from a non-manured field by as much as 67 times (Omernik et al. 1981, Sharpley et al. 1992, Hedley et al. 1995).

Reduced cover from overgrazing of grasses and other forage species results in increased sediment transport to streams and channels. Similarly, overuse of pasture land can result in soil compaction due to hoof action. During storm events and spring snowmelt, water is prevented from soaking into this compacted layer and the volume and velocity of overland flow is increased, as are the total suspended sediment and nutrient loads (NRCE 1996).

6.1.2.2.4 Livestock Grazing

Livestock grazing along streambanks and in stream channels can exacerbate erosion if improperly managed. Livestock tend to congregate where water is readily available and forage is plentiful such as in riparian areas. Increased erosion results from the grazing of riparian vegetation and from the shearing action of hooves on streambanks.

Livestock impact riparian areas and stream channels through increased sediment and nutrient loading and the deposition of manure and urine in surface waters (Mosely et al. 1997). Removal and damage of riparian vegetation leads to streambank instability and prevents the capture and entrainment of sediment at the edges of the stream channel. As a result, streambanks have become unstable in many stream reaches in the watershed (see Section 4.2).

6.1.2.3 Recreation Area Nonpoint Sources

6.1.2.3.1 Ski Areas and Forested Lands

The majority of the forested land in the upper part of the East Canyon Watershed is managed by several ski resorts. The resorts have constructed numerous roads on their properties to access and maintain facilities including ski lifts and lodges. Sediment washed from forest roads is transported to receiving waters during high flow events (Megahan 1972 and 1979, Mahoney and Erman 1984, Whiting et al. 1997). Careful management and BMPs can minimize the impact of sediment loads from roads including the restriction of OHV use and service vehicles to designated routes away from waterways and drainage areas.

6.1.2.3.2 Golf Courses

Golf courses can contribute to sediment and pollutant loads by increasing the number of impermeable (concrete) and semipermeable (turfgrass) surfaces and through over-irrigation, which washes fertilizers and pesticides into storm drains or streams.

There are currently five golf courses in the watershed, a sixth under construction, and four more golf courses proposed in the watershed. Each operating golf course currently has an individual Watershed Restoration and Protection Strategy Plan. Golf course BMPs include irrigation water management and fertilizer management. Golf course management employees must also undergo continued education and training on environmental practices (ECWC 2008b). The Parks and Golf Department manages multiple sediment traps, sediment vaults, and vegetated buffer areas.

6.1.2.4 Natural Background Nonpoint Sources

6.1.2.4.1 Phosphatic Shale

Permian phosphatic shales (Park City Phosphoric Limestone Formation) occur in two distinct locations: the Threemile and Upper Spring Creek subbasins along the southern side of Threemile Canyon, and the Treasure Hollow and Willow Draw subbasins in the extreme southeastern corner of the watershed in Park City. Many of these subbasins have been recently developed or are in active development, which has increased the erosion of phosphatic parent material into East Canyon Creek and East Canyon Reservoir (Olsen and Stamp 2000a). The phosphatic shale is a naturally occurring geologic formation that is easily eroded and contributes phosphorus adsorbed to sediment particles and has been identified as a primary source of total phosphorus loading in the watershed (BIO-WEST 2008).

6.1.2.4.2 Other background sources

Natural background loads are defined as those nutrient loads that would naturally occur under undisturbed conditions. Natural processes that contribute to background sources consist of weathering of bedrock, atmospheric deposition (dust), wildlife, natural erosion of soils, and stream channel development. Local lithology for the East Canyon watershed is primarily composed of sedimentary rock (including phosphatic shales), fine-grained alluvium and glacial outwash deposits (Olsen and Stamp 2000a).

6.1.3 Other Sources

6.1.3.1 Streambank Erosion

Population growth has lead to a rise in development in the watershed. The increase in impermeable surface area associated with residential and commercial development in the upper East Canyon watershed has resulted in flashy peak flows that contribute to streambank erosion and inputs of organic matter, nitrogen and phosphorus to receiving waters (BIO-WEST 2008). Sources of sediment and pollutants include stormwater runoff from paved areas, erosion from construction sites, and sediment and nutrients from roads and livestock. Ski areas, golf courses and livestock grazing also contribute to the potential of increased runoff and the transport of nutrients and sediment as discussed previously. Developments bordering streams have resulted in the removal and disruption of riparian vegetation, and peak storm flows have caused stream down cutting in some areas and widening in others (Bell et al. 2004).

Eroding streambanks have been estimated to contribute 2.3–7.2 tons of organic matter a year to East Canyon Creek (Baker et al. 2008). Differences in the chemical composition of streambanks and in-stream sediments suggest that approximately half of the streambank organic matter inputs are stored after entering the channel, and that organic matter may substantially increase chemical and/or biological oxygen demand (Baker et al. 2008). Sediment analyses indicate that sediment organic matter in 2000 was highest in the upper reaches of East Canyon Creek and lower downstream (Baker et al. 2008). The BIO-WEST (2008) nonpoint source study identified several stream channel reaches that are degraded and are contributing excessive amounts of sediment and phosphorus. Management actions to restore and stabilize streambanks are likely to improve DO conditions by reducing nutrient and organic matter inputs. Improvements to riparian vegetation and canopy cover would also promote the achievement of DO endpoints by reducing available light for algae and macrophyte growth and the accumulation of sediments in dense macrophyte beds. Stream channel improvements to reduce channel width and increase depth would similarly improve DO levels by increasing flow rates, scouring algae and macrophytes from the stream bed, increasing reaeration rates, and reducing light and water temperatures through deepening of channels and pools. Continued work is needed with landowners to implement and maintain stream channel restoration and rehabilitation efforts. Specific measures should include fencing the stream channel and riparian areas from livestock, channel restoration to narrow and deepen the stream, and restoration of riparian vegetation and increasing canopy cover.

6.1.3.2 Atmospheric Sources

Dust particles in the atmosphere can contribute phosphorus loads to the landscape and directly to waterbodies, although the amount depends on long term climatic and short term weather patterns and therefore varies greatly from year to year.

6.1.3.3 Internal Reservoir Sources

Phosphorus contained in reservoir bed sediments represents a significant loading source to the overlying water column of East Canyon Reservoir. The deposition, release, and dissolution of this phosphorus are dependent on both physical and chemical processes in the watershed and reservoir. Physical processes transport phosphorus contained within and adsorbed to sediment and particulate matter. Chemical processes transform phosphorus from one form (i.e., free or adsorbed) to another.

Phosphorus in the water column of East Canyon Reservoir can be divided into two major sources: suspended sediment-bound phosphorus and dissolved phosphorus. Suspended matter can be colloidal in nature (under 0.45 um in diameter) and resist settling forces because the ratio of surface area to mass is high enough that internal buoyancy counteracts gravity. Sediment and organic matter that has settled to the reservoir bottom may also become re-suspended and act as a source of dissolved phosphorus. Dissolved phosphorus may be present in tributary inflow or as phosphorus released from bottom sediments. Significant phosphorus release from bed sediments has been observed under anaerobic conditions. Phosphorus sorption sites are related to the charge state and concentration of iron and aluminum in sediment particles. Under anaerobic conditions, iron and aluminum are reduced and sorption potential is decreased, which allows the release of bound phosphorus to the water column (Sharpley et al. 1995). Low DO levels therefore lead to sediment release of bound phosphorus in this manner.

Reservoir operations that control water depth may affect the availability of sediment-bound phosphorus and its potential leaching into surface water. Fluctuating water levels that periodically expose lake sediments or alter the aerobic/anaerobic conditions at the sediment-water interface can contribute to the release of sediment-bound nutrients.

6.2 TOTAL CURRENT LOAD ESTIMATES TO EAST CANYON RESERVOIR

6.2.1 TEMPORAL EXTENT OF ANALYSIS

The time period considered representative of current loads to East Canyon Reservoir comprises the 2003–2007 water years. A water year runs from October 1 through September 31. All summaries of water quality and hydrologic data in this load analysis are specific to these time periods. Annual loads have been separated into four hydrologic periods: spring melt, storms, rain on snow, and base flow. Seasonal patterns of algal growth correspond to the hydrologic periods described above. However, internal loads from sediments play an important role in algal growth during the fall season and this load is related to watershed loads in previous seasons and years. This, in combination with the long retention time of the reservoir, has led to the decision to base the load analysis on total annual loads rather than seasonal loads.

6.2.2 METHODOLOGY

Apportionment of the total nonpoint source load among sources identified in the watershed (see Section 6.1) was achieved through application of load coefficients derived by BIO-WEST for the Upper East Canyon watershed. Total load estimates with land-use specific load coefficients were then scaled proportionally among all sources to match the calculated total load into the reservoir corresponding to the hydroperiods described above.

6.2.2.1 Calculation of Total Phosphorus Load by Hydroperiod

Total phosphorus load to East Canyon Reservoir was estimated for water years 2003 through 2007 by multiplying daily flow values by water quality concentrations extrapolated into a daily dataset based on each date's hydrologic category or hydroperiod.

A daily discharge record to East Canyon Reservoir was derived from BOR reservoir elevation and the USGS station near Jeremy Ranch, UT (#10133800). The BOR reservoir elevation dataset was corrected for evaporation and precipitation with data from the NCDC's Coalville station (see Section 3.3.1.2). This corrected inflow represents all inflow to the reservoir, including that from small tributaries entering at different points along East Canyon Creek. The corrected inflow was then divided proportionally into the inflow from East Canyon Creek and from other tributaries on the basis of basin area. The discharge record to the reservoir was categorized into four "hydroperiods" describing typical runoff conditions in the basin: spring melt, storms, rain on snow, and base flow. These periods were determined both graphically and through the use of specific criteria, using each year's annual hydrograph and daily precipitation records at the Coalville station. The methodology used for hydroperiod classification is described in Section 3.3.1.2.

Median water quality concentrations were estimated using water quality data obtained from Utah DEQ (EPA STORET), Weber Basin Water Conservancy District, SBWRD, and BIO-WEST (BIO-WEST 2008). During the post-TMDL period (2003–2007), each date was categorized into a hydroperiod as described above. Median water quality concentrations from Site 4925190 (furthest downstream site on East Canyon Creek) were determined for each hydroperiod based on available samples. Stormwater data were only available for selected sites, none of which were at the mouth of East Canyon Creek. The median storm event concentrations sampled upstream (BIO-WEST 2008) were taken for all East Canyon Creek sites and applied to the downstream site to characterize the "storm" hydroperiod. Median water quality data was then used to derive daily water quality concentration in East Canyon Creek, according to each day's hydroperiod (see Table 5.1).

Daily loads from 2003 through 2007 are calculated by multiplying daily flow values by median water quality concentrations estimated for each date (based on hydroperiod). Daily loads in East Canyon Creek were then divided into point and nonpoint sources. Point source loads were calculated directly from effluent data collected at the ECWRF. Nonpoint source loads were estimated by subtracting the ECWRF load from the total daily load in East Canyon Creek. East Canyon Creek drains approximately 72,335 acres at its inlet to the reservoir, or 78% of the watershed. Other tributary inflows to the reservoir were therefore assumed to make up approximately 22% of the total reservoir inflow for the purpose of load analysis.

6.2.2.2 Characterization of Specific Nonpoint Source Loads by Land Use and Tributary

Detailed analyses of the Summit County portion of the watershed (Upper East Canyon) were completed by BIO-WEST in 2000 and 2007. The BIO-WEST analyses estimated subbasin loads based on monitoring data and regression analysis. In addition, BIO-WEST developed load coefficients specific to the East Canyon watershed for use in determining the relative contribution of various land uses to subbasin loads. As part of this work, the NLCD land-use classes were further divided to include ski resorts, active construction, and golf courses in the analysis. These subcategories of NLCD are important contributors of nonpoint source phosphorus in the watershed.

The land-use coefficients developed for the Upper East Canyon (Summit County) portion of the watershed were applied to the Morgan County portion of the watershed based on NLCD land-use acreages. Land-use coefficients were not derived by BIOWEST for some subbasins. In these subbasins the average land-use coefficient for either phosphatic shale subbasins or nonphosphatic shale subbasins was applied as appropriate (Table 6.1). Land uses were not subdivided for the Morgan County portion of the watershed because ski resorts, golf courses, and active construction are not located in this portion of the watershed, which is dominated by agricultural and forested land uses. Instead, NLCD land-uses acreages were matched with appropriate BIOWEST land-use coefficients based on Appendix D of the BIO-WEST 2008 report. Background loads were calculated by applying the average forested/meadow land-use coefficients from the Upper East Canyon subbasins (White Pine, Kimball Creek, and Silver Creek) to the entire watershed. The difference between total loads and estimated background loads of phosphorus was assumed to be caused by land-use specific changes due to anthropogenic activities. Loads estimated from the land-use coefficients do not account for in-stream processing, rather, this process is captured by the final load estimate from East Canyon Creek as it enters East Canyon Reservoir. Loads were adjusted proportionally to match the observed load into East Canyon Reservoir from 2003–2007.

The largest proportion of the total annual nonpoint source phosphorus load (kg/year) into East Canyon Reservoir is from background sources (30%) (Figure 6.2, Table 6.2). When normalized for area, active construction, golf courses, commercial/urban areas, and ski areas compose the largest nonpoint phosphorus sources in the watershed (0.32, 0.24, 0.24, and 0.11 kg/ha, respectively) (Figure 6.3).

Table 6.1. BIO-WEST Load Coefficients (Olsen and Stamp 2000; BIO-WEST 2008) Used for East Canyon Watershed Subbasins

Subbasin	Corresponding BIO-WEST Load Coefficient
Lower East Canyon	Average of all subbasins without phosphatic shales
Direct Drainage	Middle East Canyon Watershed
Kimball Creek	Kimball Creek
Lower Springs	Spring Creek
Middle East Canyon	Middle East Canyon Watershed
Park City	Average PC Nonphosphatic
Park Meadows	Park Meadows
Red Pine	White Pine
Silver Creek/Parley's Park	Silver Creek (UEC)
Spiro Tunnel	Average of Park City subbasins with phosphatic shales
Thaynes Canyon	Average of Park City subbasins without phosphatic shales
Three Mile	Three Mile
Toll Canyon	Toll Canyon

Table 6.1. BIO-WEST Load Coefficients (Olsen and Stamp 2000; BIO-WEST 2008) Used for East Canyon Watershed Subbasins

Subbasin	Corresponding BIO-WEST Load Coefficient
Treasure Hollow	Average of Park City subbasins with phosphatic shales
Two Mile	Two Mile
Unnamed # 1	Spring Creek
Unnamed # 2	Spring Creek
Unnamed Meadow	Middle East Canyon Watershed
Upper East Canyon	Average of Upper East Canyon subbasins without phosphatic shales
Upper Spring Creek	Spring Creek
White Pine	White Pine
Willow Draw	Willow Draw
Bear Hollow	Average of all subbasins without phosphatic shales
Mann Creek	Average of all subbasins without phosphatic shales

Table 6.2. East Canyon Watershed Land-use Areas and Annual Phosphorus Loads

Land Use	Total Hectares	Percent of Watershed	Percent of Land Use Found in Subbasins with Phosphatic Shales	Annual P Load (kg/year)	Normalized P Load (kg/ha)	Percent of Annual Load
Background	26,575	71.0%	4.3%	474.7	0.0	22.9%
Forested/ Meadow	26,575	71.0%	4.3%	474.7	0.0	22.9%
Residential	5,715	15.3%	2.8%	354.2	0.1	17.1%
Ski Areas	2,982	8.0%	22.9%	315.7	0.2	15.2%
Ag/Grazing	572	1.5%	15.1%	54.5	0.1	2.6%
Golf Courses	893	2.4%	6.3%	136.9	0.3	6.6%
Active Construction	71	0.2%	24.6%	26.1	0.5	1.3%
High Use Rec	57	0.2%	0.0%	8.5	0.1	0.4%
Commercial Urban	333	0.9%	28.7%	85.3	0.3	4.1%
Open Water	235	0.6%	0.0%	-	-	0.0%
Grand Total	37,433	100.0%	6.0%	2072	n/a	100.0%

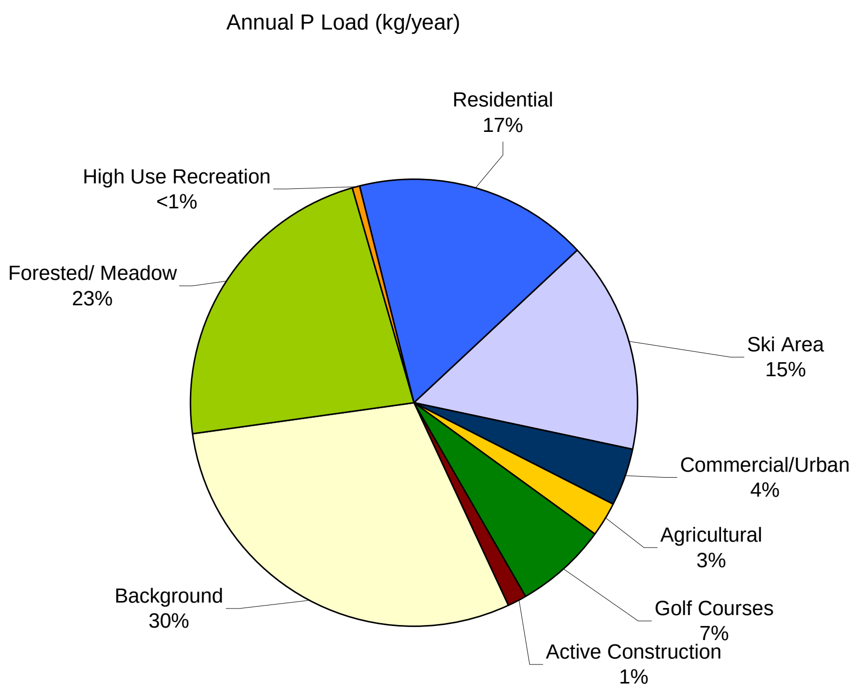

Figure 6.2. Total Annual Nonpoint source phosphorus loads (kg/year) by land use.

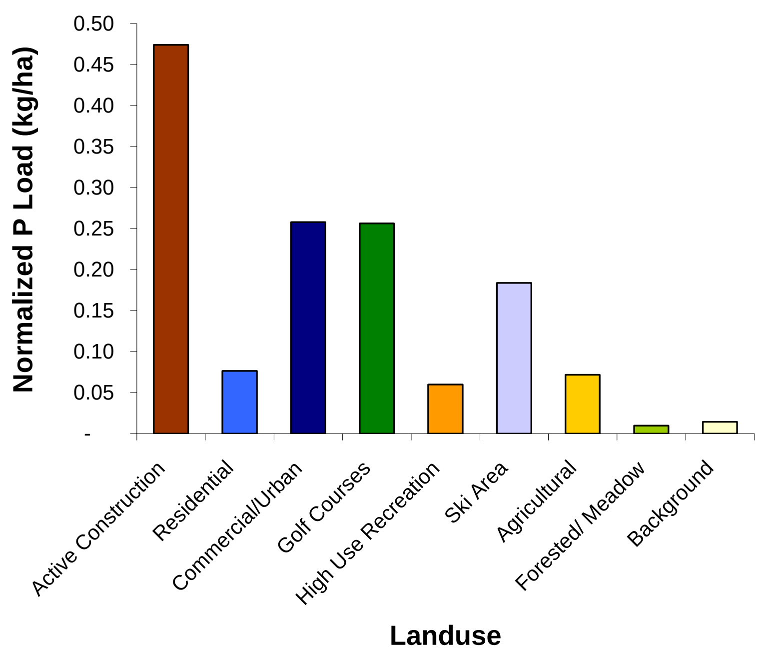

Figure 6.3. Normalized nonpoint source phosphorus loads (kg/ha) by land use.

6.2.2.2.1 Background Sources

Background or natural nonpoint source areas include the estimated natural load from all 23 subbasins. Background sources contribute 616 kg/year (0.01 kg/ha) of phosphorus, or 30% of the total annual nonpoint source load. In the East Canyon watershed, phosphatic shales occur in the Treasure Hollow, Spiro Tunnel, Upper Spring Creek, Willow Draw and Three Mile subbasins. Subbasins with phosphatic shales contribute 7% (44 kg/year) of the background annual nonpoint source phosphorus load.

6.2.2.2.2 Forested and Meadow Land Uses

Forested and meadow land-use areas compose 26,575 hectares (71%) of the watershed and includes 22 subbasins. Only the Willow Draw subbasin contains phosphatic shales. These land uses contribute 475 kg/year (0.01 kg/ha) of phosphorus, or 23% of the total annual nonpoint source phosphorus load in the watershed. Subbasins with phosphatic shales contribute 1% (7 kg/year) of the annual phosphorus load from these land uses.

6.2.2.2.3 Residential Land Use

Residential land use composes 5,715 hectares (15%) of the watershed across all 23 subbasins, including those with phosphatic shales (Treasure Hollow, Spiro Tunnel, Willow Draw and Three Mile subbasins). This land use contributes 354 kg/year (0.08 kg/ha) of phosphorus, or 17% of the total annual nonpoint source phosphorus load in the watershed. Subbasins with phosphatic shales contribute 6% (21 kg/year) of the annual phosphorus load from this land use. The residential land-use category includes loads associated with onsite wastewater treatment systems (septic systems). A groundwater study of the Silver Creek Estates area estimated that groundwater contributes an annual load of 41 to 53 kg/year of dissolved phosphorus to East Canyon Creek, some of which is associated with background concentrations (UDEQ 2003). The estimated load from the Silver Creek subbasin, using the methodology described in this section, is 103 kg/year. The majority of this load is associated with residential land uses and therefore incorporates the estimated load from groundwater described in the groundwater study (UDEQ 2003).

6.2.2.2.4 Commercial and Urban Land Uses

Commercial and urban land uses compose 333 hectares (1%) of the watershed across 14 subbasins, including those with phosphatic shales (Treasure Hollow, Spiro Tunnel, Willow Draw and Three Mile subbasins). These land uses contribute 85 kg/year (0.26 kg/ha) of phosphorus, or 4% of the total annual nonpoint source phosphorus load in the watershed. Subbasins with phosphatic shales contribute 52% (44 kg/year) of the annual phosphorus load from this land use.

6.2.2.2.5 Ski Areas

Ski areas occupy approximately 2,982 hectares (8%) of the watershed in nine subbasins, including those with phosphatic shales (Treasure Hollow, Spiro Tunnel and Willow Draw subbasins). The ski area land use contributes 316 kg/year of phosphorus, or 8% of the total annual nonpoint source load in the watershed. Subbasins with phosphatic shales compose approximately 23% of ski areas and contribute 98% (309 kg/year) of the annual phosphorus load from ski area land uses.

6.2.2.2.6 Agricultural Land Uses

Agricultural land uses (including hayland, pasture land, and irrigated crops) compose 572 hectares (1.5%) of the watershed in 12 subbasins, including high nonpoint source areas in the Direct Drainage, Middle East Canyon and Kimball Creek subbasins. The agricultural land uses are not found in any of the subbasins with phosphatic shales. These land uses contribute 54 kg/year (0.07 kg/ha) of phosphorus, or 2.6% of the total annual nonpoint source phosphorus load in the watershed.

6.2.2.2.7 Golf Courses

Golf courses compose approximately 893 hectares (2.4%) of the watershed. Golf courses contribute 137 kg/year (0.26 kg/ha) of phosphorus, or 6.6% of the total annual nonpoint source phosphorus load in the watershed. Subbasins with phosphatic shales contribute 28.37% (28.4 kg/year) of the annual phosphorus load from golf course land uses.

6.2.2.2.8 Active Construction

Active construction land-use areas compose 71 hectares (0.2%) of the watershed. Active construction contributes 26.1 kg/year (0.47 kg/ha) of phosphorus, or 1.3% of the total annual nonpoint source phosphorus load in the watershed. The majority of this load comes from the Willow Draw subbasin, which contains phosphatic shales and delivers an annual phosphorus load of 17.6 kg/year.

6.2.2.2.9 High Use Recreation

High use recreation land-use areas compose 57 hectares (0.2%) of the watershed in the Silver Creek/Parley's, Lower Springs and Murnin Creek subbasins. There are no phosphatic shales in these subbasins. This land use contributes 8.5 kg/year (0.06 kg/ha) of phosphorus, or 0.4% of the total annual nonpoint source phosphorus load in the watershed.

6.2.2.2.10 Summary of Nonpoint Source Load by Land Use

Background sources contribute the greatest proportion (30%) of nonpoint source phosphorus loads in the East Canyon watershed. Agricultural lands compose 1.5% of the watershed and contribute 54 kg/year (2.6%) of the total annual nonpoint source phosphorus load. This land use produces low phosphorus loads per hectare (0.07 kg/ha). Golf courses, ski areas, and active construction compose 10.5% (3,933 ha) of the watershed and contribute 461 kg/year (22%) of the total annual nonpoint source phosphorus load. These land uses are concentrated in the upper portion of the watershed in subbasins containing phosphatic shales, which contributes to high normalized phosphorus loads (0.18–0.47 kg/ha). Residential and commercial urban land uses compose 16.2% (6,047 ha) of the watershed and contribute 439 kg/year (21%) of the total annual nonpoint source phosphorus load. The commercial and urban land uses are concentrated in the upper portion of the watershed in subbasins containing phosphatic shale, which contributes to the high normalized phosphorus load (0.26 kg/ha) associated with land use. Residential land uses are distributed throughout the watershed at a much lower density which accounts for the relatively moderate normalized phosphorus load (0.08 kg/ha).

6.2.2.2.11 Summary of Nonpoint Source Load By Subbasin

The annual phosphorus loads associated with East Canyon watershed subbasins demonstrate both the large proportion of nonpoint source phosphorus from background, forested and meadow land uses in middle and lower subbasins (Middle East Canyon, Lower East Canyon, Direct Drainage), and the concentration of phosphatic shale, construction and development in upper subbasins (Treasure Hollow, Willow Draw, Kimball Creek) (Table 6.3; see also Figure 6.4). As discussed above, land uses associated with higher normalized phosphorus loads (kg/ha) are concentrated in subbasins in the upper portion of the watershed.

Table 6.3. East Canyon Watershed Subbasin Phosphorus Loads

East Canyon Watershed Subbasin	Hectares	Annual P Load (kg/year)	Normalized P Load (kg/ha)	Percent of Total Annual P
Bear Hollow	279	17.4	0.06	1%
Direct Drainage	8,160	345.8	0.04	17%
Kimball Creek	1,067	139.8	0.13	7%
Lower East Canyon	11,376	409.0	0.04	20%
Lower Springs	441	29.0	0.07	1%
Middle East Canyon	2,580	110.9	0.04	5%
Park City	107	13.7	0.13	1%
Park Meadows	239	41.2	0.17	2%
Red Pine	1,031	22.4	0.02	1%
Silver Creek/Parley's Park	3,049	102.8	0.03	5%
Spiro Tunnel	138	55.4	0.40	3%
Thaynes Canyon	1,333	46.8	0.04	2%
Three Mile	890	14.1	0.02	1%
Toll Canyon	1,353	72.9	0.05	4%
Treasure Hollow	268	200.6	0.75	10%
Two Mile	538	106.3	0.20	5%
Unnamed # 1	62	4.6	0.07	0%
Unnamed # 2	19	1.3	0.07	0%
Unnamed Meadow	82	3.7	0.05	0%
Upper East Canyon	1,845	110.5	0.06	5%
Upper Spring Creek	265	15.2	0.06	1%
White Pine	1,621	16.4	0.01	1%
Willow Draw	688	192.4	0.28	9%
Total	**37,433**	**2,072**	**n/a**	**100%**

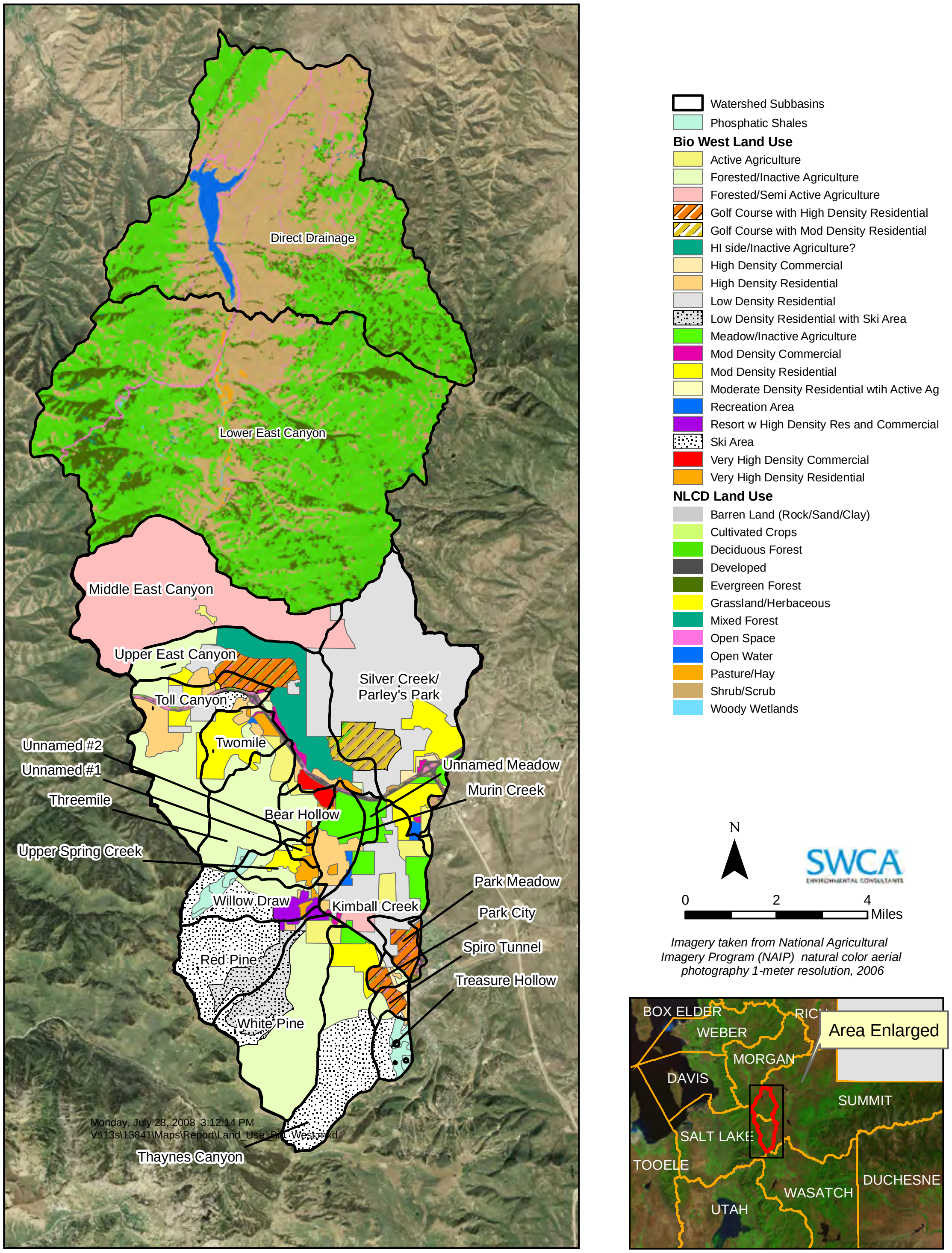

Figure 6.4. Map of land-use coverage and subbasins used in estimating nonpoint source loads to East Canyon Reservoir.

Data sources: BIO-WEST 2008 and NLCD dataset.

6.2.3 Load Summary by Hydrologic Period

The load that occurs in each hydroperiod is determined by the median concentration present and the hydroperiod's discharge magnitude and flow duration. Spring melt and base flow supply the majority of both water and nutrients from the East Canyon Reservoir watershed. Spring melt accounts for, on average, 47% of all runoff from the watershed due to the accumulation of winter snow in the upper reaches of the watershed. Despite its relatively low magnitude discharges, base flow accounts for an additional 33% of all runoff, largely due to its long duration. Rain on snow events and storms account for 16% and 4% of runoff, respectively (Figure 6.5, Table 6.4).

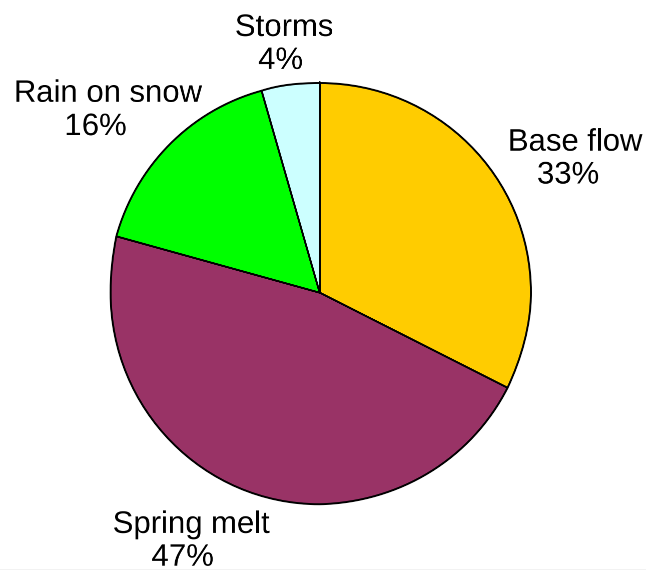

Figure 6.5. Percentage of total basin discharge (volume) from each hydroperiod.

Table 6.4. Acre-Feet of Runoff from Each Hydroperiod during the Post-TMDL Period

Water Year	Hydrologic Year	Base Flow	Spring Melt	Storm	Rain on Snow
2003	Dry	8,197	6,661	1,946	910
2004	Dry	10,734	11,340	3,348	1,947
2005	Normal	13,313	23,837	13,644	1,276
2006	Normal/Wet	16,371	32,062	8,644	2,550
2007	Normal	10,197	10,445	2,136	1,392
Average	**Normal**	**11,763**	**16,869**	**5,943**	**1,615**

As shown in Table 6.5 and Figure 6.6, the snowmelt period is the dominant source of the annual load of total phosphorus in East Canyon Creek. Mean annual precipitation in the East Canyon drainage is 26 to 37 inches (66–94 cm) per year, 73% of which occurs as snow from October to April, The high elevation snow and spring runoff from snowmelt provide most of the water to East Canyon Creek, with the highest flows occurring in April and May (BOR 2003). This runoff carries a significant load of sediment and nutrients to the stream and reservoir. In addition to high flows and a relatively long duration, the spring melt hydroperiod is characterized by the highest average concentrations of DO and much higher concentrations of total phosphorus than the base flow period (0.069 vs. 0.045, respectively, see Table 5.1). The spring melt period delivers an average of 51% of the total phosphorus from the watershed; this figure ranged from 41% of the load during a dry year (2003) to 60% of the load in a relatively wet year (2006). In addition, the spring melt period delivers an average of 53% of the dissolved phosphorus from the watershed (Table 6.6, Figure 6.7); this figure ranged from 39% of the load during a dry year (2003) to 63% of the load in a relatively wet year (2006). As such, this period will be a major target for nonpoint source phosphorus reduction from the basin.

Table 6.5. Summary of Total Phosphorus Load (kgTP/year) by Hydroperiod for the Post-TMDL Period

Water Year	Hydrologic Year	Base Flow	Spring Melt	Rain on Snow	Storms	Total	Acceptable TMDL Load (kg/year)
2003	Dry	467.41	464.77	128.23	65.28	1,125.68	1,232.34
2004	Dry	466.83	814.99	254.91	44.35	1,581.07	1,196.62
2005	Normal	702.43	1,869.76	1,122.57	124.30	3,819.06	2,902.25
2006	Normal/Wet	939.09	2,684.29	700.24	171.03	4,494.65	3,764.00
2007	Normal	737.68	752.83	155.93	108.44	1,754.88	2,103.02
Average Post-TMDL	**Normal**	**662.69**	**1,317.33**	**472.38**	**102.68**	**2,555.07**	**2,239.64**

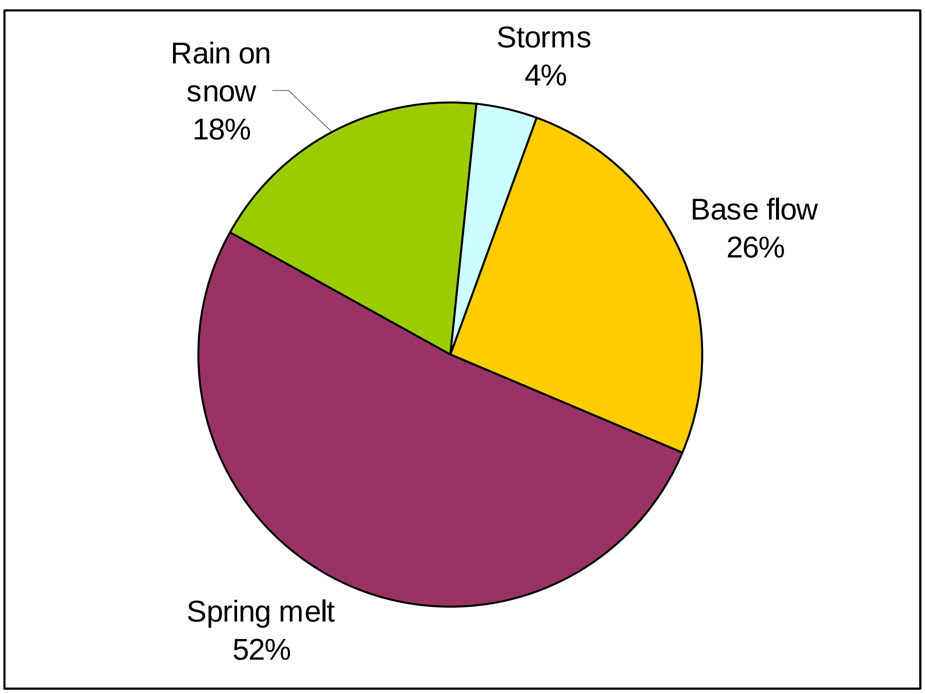

Figure 6.6. Percentages of total phosphorus load to East Canyon Reservoir summarized by hydroperiod.

Table 6.6. Summary of Dissolved Phosphorus Load (kgDP/year) by Hydroperiod for the Post-TMDL Period

Water Year	Hydrologic Year	Base Flow	Spring Melt	Rain on Snow	Storms	Total
2003	Dry	330.91	311.29	66.01	32.32	802.24
2004	Dry	365.52	535.75	114.58	24.45	1,040.30
2005	Normal	511.78	1,158.21	454.15	73.84	2,197.98
2006	Normal/Wet	695.99	1,836.67	299.33	101.22	2,933.21
2007	Normal	514.68	488.52	71.61	62.59	1,137.40
Average Post-TMDL	**Normal**	**483.78**	**866.09**	**201.14**	**58.88**	**1,622.23**

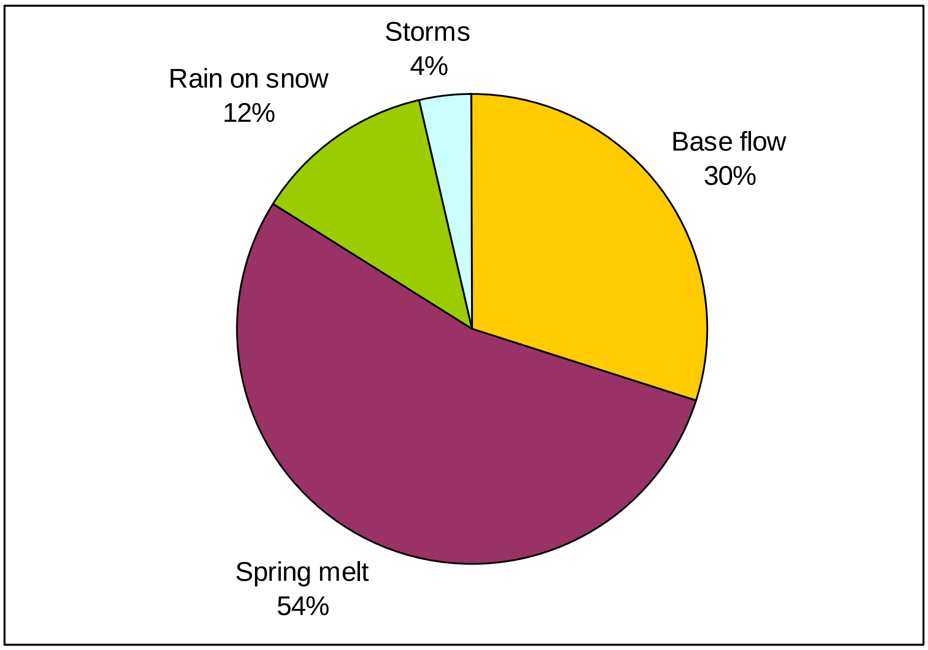

Figure 6.7. Percentages of dissolved phosphorus load to East Canyon Reservoir summarized by hydroperiod.

The second largest load of both water and phosphorus is delivered during the base flow hydroperiod. Base flows are responsible for 33% of all discharge, 26% of total phosphorus, and 30% of dissolved phosphorus, on average. Base flows follow a pattern opposite of spring melt in relatively wet and dry years; base flows tend to carry a far greater percentage of the total load in dry years (up to 42% of the TP and 45% of the DP) and a lesser percentage in wetter years (18% of TP and 23% of DP). This pattern can be explained by the relatively constant phosphorus load from ECWRF. Base flow phosphorus loads from year to year vary by approximately a factor of 2, whereas the load carried by the spring melt varies by more than a factor of 5.

Storm events occurring in the summer months produce short duration high flow events with a high load carrying capacity and significant erosion potential. However, due to their relative infrequency and low duration, storm flows account for only 4% of runoff, TP, and DP. As such, the reduction of storm flow loads will have a limited role in the TMDL implementation plan. Summer storm events are limited sources of flow as the vegetation present in the watershed may limit the amount of precipitation that actually produces runoff.

Rain on snow events account for a far greater percentage of discharge and phosphorus loading than summer storms, mainly due to their increased runoff efficiency (they occur on saturated soils and during periods of runoff) and therefore larger magnitudes. Rain on snow events account for 16% of all flows, 18% of the watershed's TP load, and 12% of the DP load.

6.2.4 Summary of Watershed Sources

The total annual watershed phosphorus load to East Canyon Reservoir includes both point and nonpoint sources. A summary of total dissolved phosphorus loads from point and nonpoint sources is shown in Tables 6.7 and 6.8.

Table 6.7. Summary of Total Phosphorus Load to East Canyon Reservoir from Point and Nonpoint Sources (kg/year)

Water Year	Hydrologic Year	ECWRF	Nonpoint	Total	Acceptable TMDL Load (kg/year)†
2003	Dry	755.04	370.64	1,125.68	1,232.34
2004	Dry	542.33	1,038.74	1,581.07	1,196.62
2005	Normal	418.87	3,400.19	3,819.06	2,902.25
2006	Normal/Wet	419.96	4,074.68	4,494.65	3,764.00
2007	Normal	277.03	1,477.85	1,754.88	2,103.02
Average Post-TMDL	**Normal**	**482.65**	**2,072.42**	**2,555.07**	**2,239.64**
Allocated Load		**663.0**	**2,723.0***	**3,386.0**	

† Load based on annual flow x 0.05 mg/L TP.

* Includes allocation for future growth.

Table 6.8. Summary of Dissolved Phosphorus Load into East Canyon Reservoir from Point and Nonpoint Sources (kg/year)

Water Year	Hydrologic Year	ECWRF	Nonpoint	Total
2003	Dry	75.52	726.72	802.24
2004	Dry	57.07	983.23	1,040.30
2005	Normal	199.95	1,998.04	2,197.98
2006	Normal/Wet	94.31	2,838.89	2,933.21
2007	Normal	38.97	1,098.44	1,137.40
Average Post-TMDL	**Normal**	**93.16**	**1,529.06**	**1,622.23**

6.2.4.1 Point Source

Discharge volume from ECWRF has ranged from a minimum of 1.33 MGD to 6.06 MGD during the peak, tourist ski season. Average effluent volume was 2.61 MGD during water years 2003–2007. In general, data are collected four times per month from the ECWRF effluent. Average monthly effluent concentrations and discharge were used to build a daily load estimate for the ECWRF. Daily loads were summarized by water year and averaged to estimate an annual average total phosphorus load to East Canyon Creek from ECWRF.

The ECWRF is the only point source in the watershed. On average, it contributes 483 kg of total phosphorus per year to East Canyon Creek, or 19% of the total load (see Table 6.7). On average, it contributes 93 kg of dissolved phosphorus as well, or 6% of the total watershed load (see Table 6.8). However, the percentage of the total phosphorus (TP) and dissolved phosphorus (DP) load that the ECWRF contributes is largely dependent on the amount of runoff. In higher water years, such as 2006, ECWRF contributed a similar total load (420 kg TP and 94 kg DP), but represented only 9% of the total TP load and 3% of the total DP load. In dry years such as 2003, the relative contribution was 67% of the TP watershed load and 9% of the DP watershed load.

In general, the load from the ECWRF is far more constant than the load from nonpoint sources and has varied by less than a factor of 3. As shown in Table 6.7, the total phosphorus load in the creek has exceeded the existing TMDL in three out of the last five years. The point source load has generally been a relatively small component of the total load, and has not exceeded the TMDL's point source allocation over that period.

6.2.4.2 Nonpoint Sources

Nonpoint sources of total phosphorus are derived from land uses and human activity in the watershed. These land uses and activities are described in Section 6.1.2, and will also be addressed in this TMDL's implementation plan. Overall, nonpoint sources of phosphorus in the watershed account for 81% of the annual load of total phosphorus, and 94% of the dissolved load (see Tables 6.7 and 6.8). Unlike the ECWRF, both the total and relative contribution of nonpoint source loads vary greatly between wet and dry years. In general, nonpoint sources produce far greater total and relative loads of TP and DP in wet years due to greater runoff and increased erosion. Dry years tend to result in far fewer nonpoint source phosphorus inputs because there is little runoff and less in-stream sediment is mobilized.

The nonpoint source load of TP has been slightly reduced since implementation of the existing TMDL from an annual load of 3,760 lbs/year to 2,072 lbs/year (UDEQ 2000b and Table 7). The nonpoint source phosphorus allocation in the existing TMDL is 1,895 lbs/year for existing nonpoint sources and 1,516 lbs/year that are reserved for growth. Assuming that the entire future growth allocation is intended for nonpoint sources, then the total nonpoint source allocation in the existing TMDL is 3,411 lbs/year. This load allocation has been achieved in every year since the 2002 with the exception of 2006 (see Table 6.7). Nonpoint sources continue to add an average of more than 2,000 kg of TP to the creek's load each year, as well as over 1,500 kg of DP.

6.2.5 INTERNAL LOAD SUMMARY

A phosphorus mass balance model was developed for East Canyon Reservoir to calculate monthly and annual net internal load from reservoir sediments. To calculate the net internal load, the total load (monthly or annual) into the reservoir was subtracted from the total load (monthly or annual) out of the reservoir. It was assumed that any phosphorus exported from the reservoir that is an input to the reservoir represents a net internal load from the sediments. Due to the long hydraulic retention time of the reservoir, internal load estimates are generally more reliable when calculated over a longer period of time. Annual internal load estimates are summarized in Table 6.9. Annual internal load is 795 kg/year on average although annual internal loads are estimated to be as high as 1,780 kgTP/year and as low as 294 kgTP/year. The high internal load observed in 2007 likely represents the high phosphorus load to the reservoir during the previous two years which were wetter the other years in the analysis. Net internal load over the entire 2003–2007 periods is 4,772 kg of total phosphorus.

Table. 6.9. Estimated Internal Load during the Post-TMDL Period

Water Year	Hydrologic Year	Percent 30-year Flow	Total P Inflow (kg/year)	Total P Outflow (kg/year)	Internal Load (kg/year)	Percent of Total that is Internal
2003	Dry	45%	1,125.67	1,877.38	751.71	40%
2004	Dry	43%	1,581.07	1,875.47	294.4	16%
2005	Normal	105%	3,819.06	4,344.63	525.58	12%
2006	Normal/Wet	136%	4,494.65	5,121.35	626.71	12%
2007	Normal	76%	1,754.88	3,532.99	1,778.12	50%
Average	**Normal**	81%	2,555.06	3,350.37	795.3	26%
Total			12,775	16,752	3,977	24%

The bulk of the internal load comes during the summer period when anoxic hypolimnetic waters facilitate the release of phosphorus into the water column. The majority of this phosphorus originated in the watershed and was washed into the reservoir during the previous spring. In other words, reservoir sediments act as a sink during the spring and a source during the summer (Figure 6.8). In addition, some legacy sources of internal phosphorus remain from decades of phosphorus loading to the reservoir. The reservoir appears to be flushing these legacy sources as it begins to establish a new steady state. The expected time for reservoir sediment flushing is estimated to be longer than 10 years, based on the W2 model simulation results.

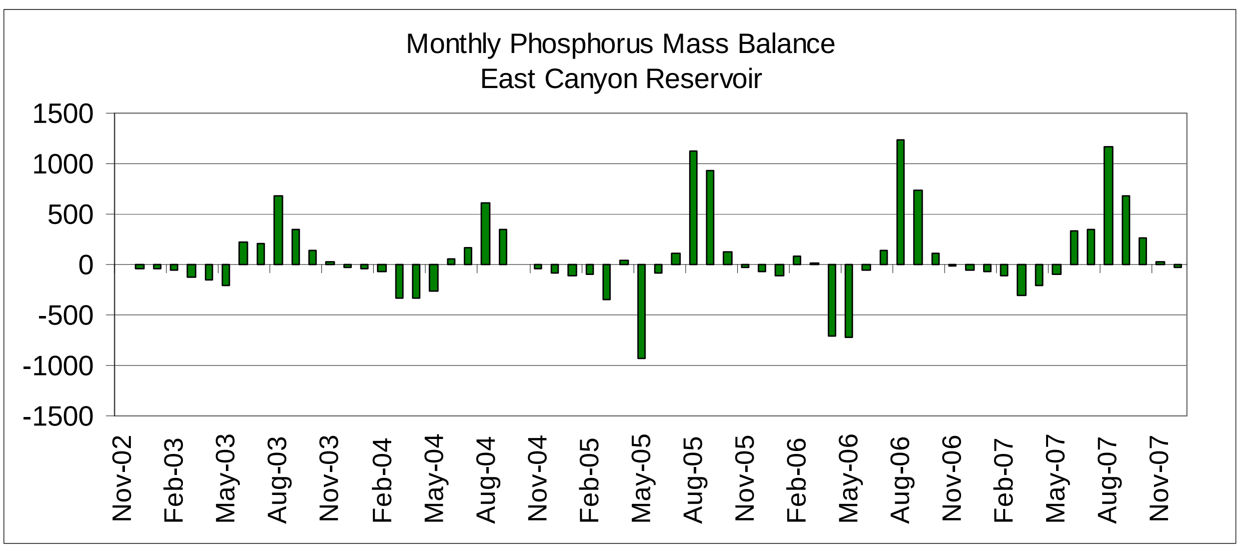

Figure 6.8. Monthly phosphorus mass balance for East Canyon Reservoir for water years 2003–2007.

Positive values represent internal load sources and negative values indicate that the reservoir is acting as a sink.

6.2.6 Total Load Summary

In total, 3,350 kgTP/year were delivered to East Canyon Reservoir on average between 2003 and 2007. This total represents an annual average watershed load of 2,555 kgTP/year (67% of the total) and an average internal sediment load of 795 kgTP/year (23% of the total). Loads and their apportionment between point, nonpoint, and internal sources varies between dry and wet/normal hydrologic years (Table 6.10).

Table 6.10. Summary of Total Phosphorus Load to East Canyon Reservoir from Point, Nonpoint, and Internal Sources (kg/year)

Water Year	Hydrologic Year	ECWRF	Nonpoint	Internal Load	Total
2003	Dry	755	371	752	1,877
2004	Dry	542	1,039	294	1,875
2005	Normal	419	3,400	526	4,345
2006	Normal/Wet	420	4,075	627	5,121
2007	Normal	277	1,478	1,778	3,533
Average Post-TMDL	**Normal**	483	2,072	795	3,350

Of the external watershed sources of phosphorus load to East Canyon Creek and Reservoir, far and away the greatest percentage (47%) come from nonpoint sources generated during the snowmelt period each spring (Figure 6.9). As such, these sources will be a major target for implementing load reductions. The second greatest load source is nonpoint phosphorus transported by rain on snow events. This is also an area that is ripe for implementing reductions. Finally, the last major sources are nonpoint and point sources transported during base flow.

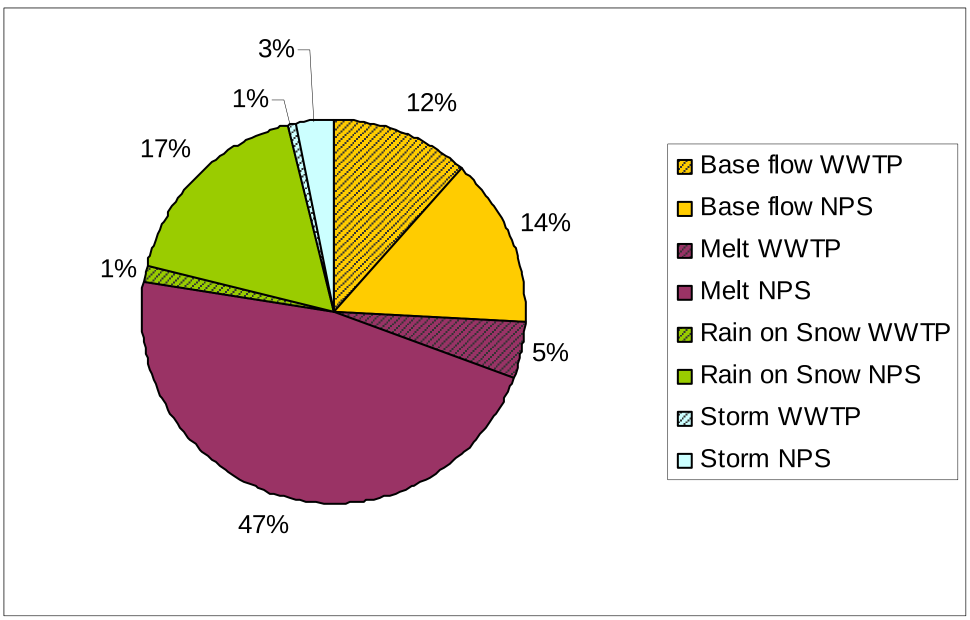

Figure 6.9. Average annual total phosphorus load by hydroperiod and source.

7. TOTAL MAXIMUM DAILY LOAD SUMMARY

7.1 PHASED TMDL APPROACH AND RATIONALE

UDWQ is currently in the process of revising the assessment methodology for DO criteria applicable to deep reservoirs that stratify during the summer season. New assessment methods will affect the monitoring strategy for deep reservoirs, the frequency of recorded water quality exceedances associated with DO, potentially the impairment status of the reservoir, and therefore the attainment of water quality standards and assessment of TMDL targets.

The current DO criteria for cold water fisheries includes 4.0 mg/L as a 1-day minimum acute criteria, a chronic criteria of 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average. When early life stages of cold water fish are present, the chronic criteria are more stringent. Under these conditions the 7-day average standard is 9.5 mg/L and the acute criteria is 8.0 mg/L minimum daily DO. Although the all-life-stage criteria are routinely attained in the epilimnion of the reservoir (see Section 3.4.1.4), the current assessment methodology requires attainment in 50% of the water column. During stratified periods the hypolimnion becomes anoxic and accounts for more than 50% of the water column. Furthermore, although the epilimnion has sufficient levels of DO for fish, the water temperature in this upper layer is too warm for most cold water fish species.

In the interim, although new assessment methods are developed, site-specific assessment methods have been identified for East Canyon Reservoir, in conjunction with the Utah Division of Wildlife Resources, for the purposes of developing this TMDL. These assessment methods, described in Section 7.2.1.1, are specific to the intersection of the acute DO standard of 4.0 mg/L and the temperature standard of 20°C in 2 m of the metalimnion. Establishing a 2-m refuge for cold water game fish in the metalimnion, where both temperature and DO criteria are simultaneously attained, is believed to be protective of the existing cold water fishery in East Canyon Reservoir.

EPA guidance recommends the development of a phased TMDL when water quality standards are expected to be revised in the near future. A phased TMDL allows for TMDL revisions to comply with new standards (or in this case assessment methodology) in the future. For this reason, the UDWQ has elected a phased TMDL approach for the East Canyon Reservoir TMDL. EPA guidance also recommends the use of a phased TMDL when there is uncertainty associated with the TMDL analysis. Uncertainty in the East Canyon Reservoir TMDL is associated with the following factors:

- Total phosphorus and DO linkage
- Nonpoint source reduction effectiveness
- Time required to achieve all water quality standards

EPA recommends that phased TMDLs include implementation and monitoring plans as well as a scheduled time frame for revision of the TMDL. The implementation plan (see Chapter 9) developed to attain the load reductions to East Canyon Reservoir identified in this TMDL includes all of the required components of a watershed-based plan (EPA 2008), including a monitoring plan. Interim water quality milestones have also been identified in the watershed-based implementation plan.

In addition, UDWQ has scheduled the East Canyon Reservoir TMDL to be reevaluated in 2019. Ten years is believed to be an appropriate amount of time for revisiting the East Canyon Reservoir TMDL for the following reasons:

- Ten years provides sufficient time for implementation of nonpoint source management measures and for monitoring their effectiveness in improving water quality.

- Expansion of the ECWRF, the point source in the watershed, is expected to commence in 2011 with a completion date of 2015. Ramp up to full capacity of the expanded treatment facility is not expected until 2038 under current growth conditions, so there is no immediate threat of a higher phosphorus wasteload associated with this source.
- Ten years is a sufficient period of time for the reservoir to flush the majority of excess phosphorus residing in bottom sediment and/or for sediments that are less phosphorus rich to cover the top of the existing sediment. Release of excess phosphorus has been documented in the past five years and is associated with reduced total phosphorus inputs to the reservoir.
- Revisions to water quality standards and assessment methodology will be completed in this time frame.

If water quality targets have not been achieved by 2019, UDWQ will reevaluate the East Canyon Reservoir TMDL and consider the following additional steps:

- Use Attainability Analysis
- Site-specific water quality standards
- examination of other causative factors of the low DO water quality impairment such as water management or organic matter loading

These steps would only be taken after nonpoint source reduction projects have been fully implemented. At this point, further phosphorus reductions would be difficult to attain due to the high background load of phosphorus in the watershed associated with naturally occurring phosphatic shales. If nonpoint source projects have not been fully implemented by 2019, a formal water quality trading program would be considered.

7.2 WATER QUALITY TARGETS AND LINKAGE ANALYSIS

Setting water quality endpoints is critical in the TMDL development process. The goal of the East Canyon Creek and East Canyon Reservoir TMDLs is to achieve state water quality criteria to bring designated beneficial uses into full support as quickly as possible. Setting appropriate water quality endpoints is a key prerequisite to the calculation and apportionment of current pollutant loads and the necessary load reductions to support designated beneficial uses. Several methods were employed to derive water quality endpoints for East Canyon Creek and East Canyon Reservoir.

The State of Utah has designated East Canyon Reservoir and East Canyon Creek as protected for cold water game fish (Class 3A). This designated beneficial use was identified as impaired on the State of Utah 1998 303(d) list for the reservoir and the 1992 303(d) list for the creek. Dissolved oxygen endpoints are based on State Water Quality criteria and, together with warm temperatures, are the direct cause of the impairment of cold water fisheries (3A) in the creek and reservoir. Low DO in the reservoir is related to the decomposition of algae and subsequent depletion of DO in the hypolimnion. Low DO in the creek is primarily related to respiration of macrophytes and periphyton, in addition to sediment oxygen demand from decaying organic matter. Macrophyte- and algae-related endpoints were selected based on the direct and indirect influence of plant biomass on DO concentrations in both waterbodies and identified nuisance algal thresholds that are considered to be protective of recreational beneficial uses in the reservoir. These endpoints were based on several recent studies of water quality in the East Canyon watershed (East Canyon SVAP; SBWRD 2005; BIO-WEST 2008; Baker et al. 2008; SBWRD 2008; see Chapter 4 for summary), a review of relevant scientific literature, and results from the East Canyon Reservoir W2 model developed by JM Water Quality LLC. Total phosphorus endpoints for the reservoir are based on the correlation between chlorophyll *a* targets and mean seasonal total phosphorus concentration derived from the W2 modeling results. No nutrient targets have been established for East Canyon Creek because the DO impairment in East Canyon Creek was found to be due to physical stream conditions characterized as light, temperature, and low flow ***pollution*** rather than by nutrient ***pollutants***.

7.2.1 DISSOLVED OXYGEN ENDPOINTS

Dissolved oxygen is important to the health and viability of the cold water fishery beneficial use (3A). High concentrations of DO (6.0–8.0 mg/L or greater) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause increased stress to fish species, lower resistance to environmental stress and disease, and result in mortality at extreme levels (less than 2.0 mg/L).

7.2.1.1 East Canyon Reservoir

The DO endpoints for East Canyon Reservoir are consistent with existing Utah water quality criteria and were developed in collaboration with the Utah Division of Wildlife Resources. During periods of complete mixing in the reservoir, all life-stage water quality criteria identified by the State of Utah will be maintained across the reservoir and throughout at least 50% of the water column. The DO criteria include 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average. Cold water sport fish species are not known to reproduce in the reservoir, therefore the early life-stage criteria do not apply. These criteria are all currently attained in the epilimnion of the reservoir. However, the epilimnion routinely exceeds temperature criteria during the summer season due to solar radiation (see Section 3.4.1.4). To protect the fishery from the intersecting pressures of high temperature in the epilimnion and low DO in the hypolimnion, the following site-specific assessment methodology was selected for this TMDL: During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20^{o}C shall be maintained in a 2-m layer across the reservoir to provide adequate refuge for cold water game fish. These criteria were determined to provide sufficient support for the cold water game fish beneficial use (3A) designated by the State of Utah for East Canyon Reservoir.

These endpoints apply to normal climatic conditions defined by variable hydrologic conditions across consecutive years, with annual flow within 50% of the 30-year average and current water management regimes. Under conditions of consecutive drought or wet-flow years, the criteria may not be achieved. In addition, periods of extreme spring runoff flows or summer storms may produce conditions that periodically do not attain the criteria. These criteria were used to derive total and dissolved phosphorus endpoints for the reservoir as well as algal-related endpoints. Water quality could also be affected, both positively and negatively, in the future under different water management practices. For example, the Bureau of Reclamation is currently considering a proposal by Summit Water to withdraw up to 12,500 acre-feet/year of water from East Canyon Reservoir for use in Snyderville Basin and Park City area (BOR 2008).

7.2.1.2 East Canyon Creek

The DO criteria identified for creeks and streams requires that DO be maintained above 4.0 mg/L DO to fully support the cold water fishery beneficial use. Attainment of the acute 1-day criterion of 4 mg/L is considered to also represent compliance with the 7-day and 30-day criteria. Therefore, the 1-day criterion was used to assess proposed scenarios using the DIURNAL model.

The only cold water game fish found to spawn in East Canyon Creek is Brown Trout (personal communication between Erica Gaddis, SWCA and Paul Burnett, Utah Division of Wildlife Resources, September 18, 2008). Brown trout spawn in late fall (November or early December) and hatch in late February or early March. The small alevins remain in the nest for five to six weeks before emerging from the gravel as fry around mid-April. The period following emergence from the gravel is the most critical period of the life cycle which continues through mid-May. The trout remain in their natal stream as juveniles for the first year of the life cycle. The most critical period for high DO during the spawning period is while the eggs are in the nest (Elliott 1994). Therefore, early life-stage criteria for DO apply from November through May in East Canyon Creek. These criteria require that DO be maintained above 8.0 mg/L DO. Attainment of the acute 1-day criterion of 8 mg/L is considered to also represent compliance with the 7-day and 30-day criteria. There are currently no documented exceedances of the early life-stage criteria during the period of November through May. Because spawning does not occur during summer months (June, July, and August) these early life-stage criteria do not apply. The all life-stage criteria, which do apply during summer months, have been used as the primary endpoints for the East Canyon Creek TMDL.

7.2.2 Macrophyte-related and Algae-related Endpoints

Overgrowth of algae violates the narrative standard for waters established by the State of Utah, which requires waters to be maintained such that they do not become offensive by "unnatural deposits, floating debris, oil, scum, or other nuisances such as color, odor or taste…or result in concentrations or combinations of substances which produce undesirable human health effects…" (Utah State Code, Title R317).

Macrophyte and algae can have both beneficial and detrimental impacts on aquatic life in shallow freshwater ecosystems. Macrophytes and algae provide habitat and food; however, diurnal oxygen fluctuations related to nocturnal plant respiration are stressful to fish. Plant overgrowth and high water temperatures can exacerbate water quality conditions. High rates of plant growth and respiration cause diurnal DO fluctuations, and elevated temperature reduces the solubility of oxygen in water while increasing the metabolic requirements of fish. High water temperatures often occur near the surface, and fish seek deeper levels to avoid the warmer water, but deeper waters in the systems addressed here are more likely to be anoxic or low in DO and therefore are of limited use as refugia for fish. Developing embryos and young emergent fish are especially sensitive to changes in DO concentrations. Small fish would likely seek shelter along creek shoreline (littoral) areas, which provide the best vegetative cover. As these areas experience the changeover from photosynthesis to respiration at night, the shallow water column can quickly become depleted of oxygen and young fish can be stressed or die due to low DO concentrations.

In addition to algal overgrowth, algae speciation is important for protection of beneficial uses in East Canyon Creek and East Canyon Reservoir. Blue-green algae blooms can cause the formation of surface scums and the potential release of toxins harmful to humans, livestock, and pets. Although there are no reports of toxic cyanobacteria blooms in the East Canyon watershed, the potential for blooms has been demonstrated by the episodic dominance of blue-green algae species in the reservoir (see Sections 3.2.2.2 and 3.4.2.5). Macrophyte- and algae-related endpoints were selected to reduce the direct and indirect effects of plant overgrowth on DO concentrations, and to be protective of recreational beneficial uses.

7.2.2.1 East Canyon Reservoir

Macrophyte-related and algae-related water quality endpoints were selected to reduce the direct and indirect influence of decomposition associated with degradation of algal bloom biomass on DO concentrations. Periodic overgrowth of algae violates the narrative standard for waters established by the State of Utah. Therefore, algal endpoints were also selected for their protection of recreational beneficial uses. Three algal related endpoints were identified for East Canyon Reservoir:

1. Mean seasonal chlorophyll *a* values of 8.0 μg/L (based on a mean TSI value of less than 50)
2. Chl *a* concentrations to exceed nuisance threshold of 30 μg/L less than 10% of the season.
3. Maintain dominance by algal species other than blue-green algae

The mean seasonal chlorophyll *a* endpoint was derived from the Carlson Trophic State Index equation and corresponds to a chlorophyll *a* TSI of 50. Analysis of current data for the reservoir indicates that total phosphorus and Secchi depth TSIs may not be appropriate for East Canyon Reservoir due to the unique hydrodynamic characteristics of the system. Therefore, only the chlorophyll *a* TSI was used to derive endpoints for the reservoir.

A review of the recreational use literature indicates that nuisance algal concentrations for recreational beneficial uses range from 25 μg/L (Walker 1985; Raschke 1994) to 40 μg/L, with severe nuisance concentrations recognized as occurring above 60 μg/L (Heiskary and Walker 1995). Human perceptions of aesthetics and swimability are subjective and dependent on the expectations and tolerances of the public. One way to quantify the effect of chlorophyll *a* on these uses is to survey users of a waterbody and correlate their responses to water quality variables (e.g., chlorophyll *a*, Secchi disk depth, and phosphorus). This method has been used by several authors. Heiskary and Walker (1988) collected user-perception data from three groups of lake monitors in Minnesota. User survey responses were used to assign four support levels of the "swimmable" designated use (Smeltzer and Heiskary 1990). The four support levels are presented in Table 7.1.

Table 7.1. Summary of Support of Swimming Designated Use at Varying Frequencies of High[1] Algal Levels

Frequency of High Algal Levels	Support Levels of the Recreation Designated Uses
<10%	Fully supporting
11–25%	Fully supporting—threatened
26–50%	Partial support—impaired
>50%	Nonsupport—impaired

Source: Smeltzer and Heiskary 1990.
[1] The perception of 'high' algal levels was found to differ by region.

Mean chlorophyll *a* concentrations detected in East Canyon Reservoir from 2002 to 2007 ranged from 1.4–5.4 μg/L with a maximum concentration of 27.1 μg/L, which is below the literature-based threshold identified as protective of recreational activities (15–30 μg/L). However, these data are considered to be an underrepresentation of chlorophyll *a* in the reservoir due to wind patterns and sampling frequency. Nonetheless, there have been no visitor reports of "unswimmability" or aesthetic complaints related to algae in East Canyon Reservoir (see Sections 3.4.2.7 and 3.4.4).

A summary of chlorophyll *a* data from 1990 to 1998 in Ecoregion 2 (Western Forested Mountains) is provided below (Table 7.2). The statistical summaries are based on data from 441 lakes and reservoirs and include 3,931 records for chlorophyll *a*. The nutrient criteria technical guidance manual (EPA 2000) suggests that the lower 25th percentile of ecoregional data is representative of the reference condition, when not all lakes and reservoirs are considered to be in the reference condition. The 25th percentile data for ecoregion range from a low of 1.4 µg/L in the summer to a high of 3.5 μg/L in the winter. These values are below the range of the chlorophyll *a* endpoint recommended for East Canyon Reservoir and provide assurance that the targets are achievable and are not excessively low.

Table 7.2. Summary Statistics for Chlorophyll *a* (*μg*/L) Data from Lakes and Reservoirs in the Western Forested Mountains Ecoregion

Season	25th Percentile	Median	75th Percentile
Fall	1.8	3.1	6.7
Spring	2.1	4.4	8.6
Summer	1.4	2.9	5.9
Winter	3.5	5.8	6.2

Prior to 2003, blue-green algae dominated the East Canyon Reservoir system from approximately July to the end of October. Since phosphorus reductions were implemented in 2004, algal succession has shifted from July blue-green algal blooms to late October blooms. After 2006, blue-green algae were estimated to compose less than 5% of the total annual algal biomass both in the phytoplankton count data (Rushforth 2001, 2003, 2005, 2007 reports) and in the W2 model simulations. This indicates an attainment of one of the endpoints identified in the 2000 TMDL, which required algal dominance to be other than blue-green. This endpoint remains for the 2008 TMDL.

7.2.2.2 East Canyon Creek

Excessive biological activity during the growing season in the form of periphyton and macrophyte growth was indicated as the cause of low nocturnal DO levels in the original East Canyon Creek TMDL (UDEQ 2000). The 2000 TMDL also listed a maximum macrophyte coverage endpoint of 25–50%. August 2007 macrophyte cover was as high as 80–90% in 2 of 6 reaches sampled (Baker et al. 2008). A TMDL endpoint was not established for periphyton in 2000 (UDEQ 2000a).

July and August 2007 periphyton cover ranged from approximately 5% to 75% cover in the 6 stream reaches sampled (Baker et al. 2008). Baker et al. (2008) found the number of days below 4.0 mg/L DO to be highly correlated with August macrophyte cover (R^2 = 0.93) (2000 monitoring data). This correlation is supported by the DIURNAL model results (SBWRD 2008), which showed reduced diurnal DO swings in response to reduced sunlight. A 25% reduction in maximum photosynthesis P_{max} resulted in an increase in modeled minimum August DO concentrations from 3.7 mg/L to 4.5 mg/L, and a 50% P_{max} reduction increased minimum DO to 5.3 mg/L. Similar responses were predicted for both the Bear Hollow and Blackhawk water quality monitoring stations. A 25% reduction in photosynthesis is expected to achieve the 1-day water quality standard of 4.0 mg/L minimum DO identified by the State of Utah for East Canyon Creek.

Baker et al. (2008) measured total biomass for macrophytes, epiphyton, and epilithon in 6 reaches in East Canyon Creek. A 25% reduction of photosynthetic rate (and biomass) requires total periphyton and macrophyte biomass to be reduced to a maximum of 6.3 mg/cm^2. The recommended biomass was derived from modeled increases in DO with a 25% reduction in photosynthetic rates (P_{max}) and current total periphyton and macrophyte biomass in reaches with minimum DO concentrations less than 4.0 mg/L.

7.2.3 Linkage Analyses

7.2.3.1 Nutrient Targets and Water Quality Endpoints in East Canyon Reservoir

The primary contributors to low DO in East Canyon Reservoir are sediment oxygen demands related to annual algal blooms, legacy organic matter, and annual organic matter washed into the system. The W2 model found that decomposition of watershed-derived organic matter represented a minor component of oxygen depletion in the hypolimnion (see Section 5.3.3.7). Model simulations indicate that internal phytoplankton production is driven by dissolved phosphorus concentrations in the epilimnion and upper sections of the hypolimnion during stratified periods and in the surface water layers of the reservoir during mixed periods. Algal blooms throughout the year contribute to sediment oxygen demand and oxygen depletion in the reservoir. Dissolved phosphorus is delivered to the epilimnion through three processes: tributary flow directly to the epilimnion (dominates in the spring/summer), sediment release and diffusion up to the epilimnion, and mixing of the water column during fall turnover (dominates in the fall). Reduction of all of these sources is required to reduce the trophic state of the reservoir and improve DO profiles especially during stratification.

The W2 model was used to correlate DO endpoints and chlorophyll *a* endpoints with mean seasonal nutrient concentrations (see Section 5.5). A mean seasonal chlorophyll *a* target of 8 *µg*/L is correlated with a mean total and dissolved phosphorus concentration in the reservoir of 0.04 mg/L and 0.03 mg/L respectively. However, attainment of the DO endpoints specific to East Canyon Reservoir correlate with mean seasonal total and dissolved phosphorus concentrations of 0.03 mg/L and 0.02 mg/L respectively. These concentrations will therefore serve as the nutrient endpoints for East Canyon Reservoir.

7.2.3.2 Stream Characteristics and Water Quality Endpoints in East Canyon Creek

The primary impairment on East Canyon Creek relates to low nocturnal DO caused by respiration of macrophytes and periphyton. The 2000 TMDL had assumed that excess macrophyte and periphyton growth was driven primarily by excessive nutrients (principally phosphorus) in the water column (UDEQ 2000). Phosphorus reductions were intended to produce significant reductions in nuisance macrophyte and/or algal growth that impairs water quality and stream habitat. However, implementation of the 2000 TMDL does not appear to have reduced macrophyte and periphyton biomass. Baker et al. (2008) and HydroQual (SBWRD 2008) determined that the overabundance of aquatic macrophytes in the creek is currently driven by sediment accumulation, widened channel conditions, shallow water levels, low streamflow during the summer, and a lack of stream shading. Phosphorus concentrations were not identified as a controlling factor in algae and macrophyte densities.

Since the 2000 TMDL, there have been dramatic reductions in point source phosphorus, whereas rapid growth and development in the upper watershed have resulted in increased water demand and nonpoint source nutrient and sediment inputs. Sediment loading from nonpoint sources, elevated water temperatures, and overgrowth of algae and macrophytes is currently the primary cause of water quality impairments in East Canyon Creek. Nitrogen has been identified as the most likely limiting nutrient in the water column, pore waters, and sediments, and it appears that phosphorus is no longer the primary factor contributing to low DO concentrations in the creek (Baker et al. 2008). Olsen and Stamp's 2000 study of East Canyon Creek water quality found 30% less macrophyte cover in stream reaches with stable banks, abundant overhanging vegetation, and low percentage of fine sediments. Further, Baker et al.'s 2008 study of East Canyon Creek water quality identified a strong correlation between macrophyte density and low DO concentrations (<4.0 mg/L). Baker et al. (2008) also found higher photosynthetic rates in low-gradient, slow-flowing portions of the creek (see Sections 4.4 and 4.6.5). In support of these findings, the SBWRD (2008) DIURNAL model demonstrated that increased streamflow, increased riparian shading, and changes to stream geometry were all effective in reducing macrophyte productivity and increasing DO concentrations.

Management of physical stream conditions contributing to reduced flows, sediment inputs, and overgrowth of aquatic vegetation will be required to achieve these endpoints. Improvements to stream water quality can be achieved through the following mechanisms: reducing sediment inputs from nonpoint sources and streambank erosion, reducing sediment accumulations, improving stream channel geometry, increasing flows, and increasing riparian stream shading. A 4.0 mg/L daily minimum was used to model water quality and diurnal DO concentrations in response to three potential channel management strategies for East Canyon Creek (SBWRD 2008): increased streamside shading, changes to channel width/depth; and increased base flow using the Bear Hollow and Blackhawk water quality monitoring stations for evaluation (see Table 4.4). For the worst-case month (August), there were improvements in minimum DO levels at all reaches predicted to be impaired using the baseline calibration from 2007 for all of the modeled management scenarios (Table 7.3; SBWRD 2008). A 25% reduction in photosynthetic rate (P_{max}) or an increase in flow of 5 cfs during August would lead to attainment of the DO standard throughout East Canyon Creek.

Table 7.3. Projected Minimum Dissolved Oxygen (mg/L) in August for the Blackhawk and Bear Hollow Reaches of East Canyon Creek under Baseline Conditions and Management Scenarios

	Blackhawk (SVAP rch 23)	Above WWTP (SVAP rch 21)	Bear Hollow (SVAP rch 18)	Mormon Flat (SVAP rch 17)
Baseline				
2007 calibration	3.4	3.6	3.7	3.7
Stream Shade Scenarios (reduction in photosynthetic rate)				
25% P_{max} reduction	4.3	4.5	4.5	4.6
50% P_{max} reduction	5.3	n/a	5.3	n/a
Channel Width Reduction Scenarios				
25% width reduction	3.9	4.1	4.2	4.3
33% width reduction	4.1	n/a	4.3	n/a
Increased Base Flow Scenarios				
5 cfs additional flow	4.6	4.7	5.0	4.4
10 cfs additional flow	4.3	n/a	4.6	n/a

Multiple studies (Feminella et al. 1989; Hill et al. 1995; Kiffney et al. 2003) have demonstrated the effectiveness of riparian shading in limiting aquatic vegetation growth, and have direct applicability to identifying target conditions in East Canyon Creek. Feminella et al. (1989) found a significant negative relationship between periphyton biomass and riparian canopy % cover ($r = -0.67$, $P<0.0001$) for a range of 0–15 mg/cm^2 ash free dry mass (AFDM) and 15–98% canopy cover. The empirical model described in this study was used to link the recommended 25% reduction in photosynthesis (SBWRD 2008) to a recommendation for stream shading. It is assumed that the correlation between periphyton and % riparian shading identified by Feminella et al. (1989) is similar to the relationship between macrophytes and percent shade. The equation developed by Feminella et al. (1989) is

$$y = 7.75–0.06x$$

where x = % riparian cover and y = AFDM measured in mg/cm^2. Assuming a macrophyte biomass of 6.8 mg/cm2 (a value that is within the range of macrophyte biomass observed in East Canyon Creek), the model estimated that increasing riparian percent cover from 16% to 44% would reduce macrophyte AFDM by 25%.This model will be applied on a reach-by-reach basis to determine the amount of riparian shading needed to reduce aquatic vegetation cover to levels supportive of a minimum 4.0 mg/L DO concentration.

Chlorophyll *a* concentrations can vary with changing light and self-shading conditions, so AFDM accounts for all components of periphyton growth (algae, fungi, bacteria, detritus) (Feminella et al. 1989). Presumably, macrophytes could be similarly affected by dense cover of epiphyton on leaves or other photosynthetic structures. Periphyton growth in the creek is composed of both epilithon growth attached to structures in the stream channel and epiphyton growth attached to macrophyte structures. Epilithon has been shown to have reduced ratios of photosynthetic rates to biomass due to self-shading (Hill et al. 1995).

The SBWRD (2008) DO modeling study also found a 33% reduction in channel width to be effective in achieving the 4.0 mg/L DO endpoint due to increased depth, increased stream velocity, increased reaeration, and reduced productivity by algae and macrophytes.

Minimum streamflow goals for East Canyon, Kimball, and McLeod creeks were identified in the East Canyon Creek flow augmentation feasibility study to maintain water quality and fish habitat (SBWRD 2005). The recommended flows are 3.5 cfs in upper McLeod Creek; 5 cfs in Kimball Creek (3.5 cfs under extreme conditions); and 6 cfs in East Canyon Creek (3.5 cfs under extreme conditions). These minimum flow goals could be met with the addition of less than 300 acre-feet of water over 2–3 months, an addition of 1.6–2.5 cfs during summer months of dry years. These goals are not attainable with management of existing flows, and will require acquisition of in-stream water rights or direct addition of flow to the creek. The increasing growth and water use demands in the upper East Canyon watershed further limit the feasibility of attaining minimum streamflow goals without explicit changes to water management in the basin. The proposed East Canyon pipeline would pump 5,000 acre-feet of water per year from East Canyon Reservoir back to Snyderville Basin, but would not provide flow augmentation above the Summit Water treatment plant. Increased flow in the creek is expected to increase DO concentrations due to reduced macrophyte and periphyton densities, reduced build-up of sediments, and increased reaeration. The SBWRD (2008) DO model found the proposed 6.9-cfs pipeline flow increase could potentially increase the lowest minimum August DO concentrations in the creek by approximately 0.7–1.3 mg/L. Increased flows are also likely to initially cause the transport of nutrients and organic matter into the reservoir until accumulated sediments, algae, and macrophyte biomass have been removed.

The SBWRD (2008) DIURNAL model recommendations (increased shading, channel modification, and establishing a protected base flow) will be evaluated on a reach-by-reach basis in the implementation phase of this project. An optimal combination of the recommended model parameters (25% reduction in P_{max}, 33% reduction in stream channel width, and a 5-cfs increase in flow) will be developed for each reach based on cost effectiveness and attainability.

Sediment reductions, associated with nonpoint source controls required for the phosphorus reductions identified for East Canyon Reservoir, will provide further improvement to DO and stream geomorphology in East Canyon Creek. Because these reductions were not included in the analysis, they provide an additional conservative assumption to attainment of DO criteria using physical means described above (shade, establishing a protected base flow, and bank stabilization).

7.3 FUTURE GROWTH

The population in Synderville Basin is expected to more than double by 2030. Population estimate reports show Park City growing from 7,497 in 2005 to 16,312 in 2030, a 54% increase. Summit County lands in the Snyderville Basin are expected to accommodate 31,887 people by 2030; a 51% increase from 15,734 people in 2005 (see Section 2.2.2 for population projections). The majority of new residential development is likely to occur on the basin floor and on hillsides with less than a 25% slope. Commercial development will be concentrated along Interstate 80 and Highways 224, 40, and 248. A large portion of the Snyderville Basin is primarily zoned for residential development. The Rural Residential Zone District (Figure 7.1) allows existing residential uses to continue and allows for the construction of new single family dwelling units. The base density is 1 unit/per 20 acres on developable lands and 1 unit/40 acres on sensitive lands. The Hillside Stewardship Zone District accommodates residential development in areas that contain slopes ranging from 15% to 25% with a base density of 1 unit/30 acres on developable lands and 1 unit/40 acres on sensitive lands. Lands in this zone are more susceptible to erosion, and development in these areas may negatively affect water quality. Residential development in the Mountain Remote Zone District is minimal (1 unit/120 acres on developable and sensitive lands) because the location and terrain do not allow for easy access to local service providers. Development in the Mountain Remote Zone is also minimized in order to protect the natural environment and water quality, to lessen fire danger, to minimize viewshed disturbances, and to promote the open space values of the Snyderville Basin (Summit County 2008). Commercial development and light industry are concentrated along I-80 and Highways 224, 40, and 248. Densities for the Community Commercial Zone and Service Commercial/Light Industrial Zone are not specified. In the Neighborhood Commercial Zone, no single structure will contain more than 5,000 square feet.

New residential and commercial development in the Snyderville Basin will require additional connections to the East Canyon Water Reclamation Facility (ECWRF). The service area for the Snyderville Basin Water Reclamation District (Figure 7.2) is virtually identical to the boundaries delineated in Summit County's Snyderville Basin Zoning Map (see Figure 7.1). As evidenced by the land-use map (see Figure 2.14), the majority of undeveloped land is shrub/scrub, agricultural land, open space, or forest. SBWRD has determined that anticipated growth in their service district will require expansion of ECWRF. Current average daily flow from the ECWRF is 2.65 MGD with peak flows of approximately 6 MGD during the peak recreation season in the winter. Accommodation of the expected population growth in the basin will require expansion of the treatment system with an average discharge of 7.2 MGD. The expanded treatment system will be designed such that the concentration of nutrients will remain low, as they are today, with projected average total and dissolved phosphorus concentrations of 0.10 and 0.03 mg/L. The load allocated to the ECWRF is based on these flow and concentration assumptions.

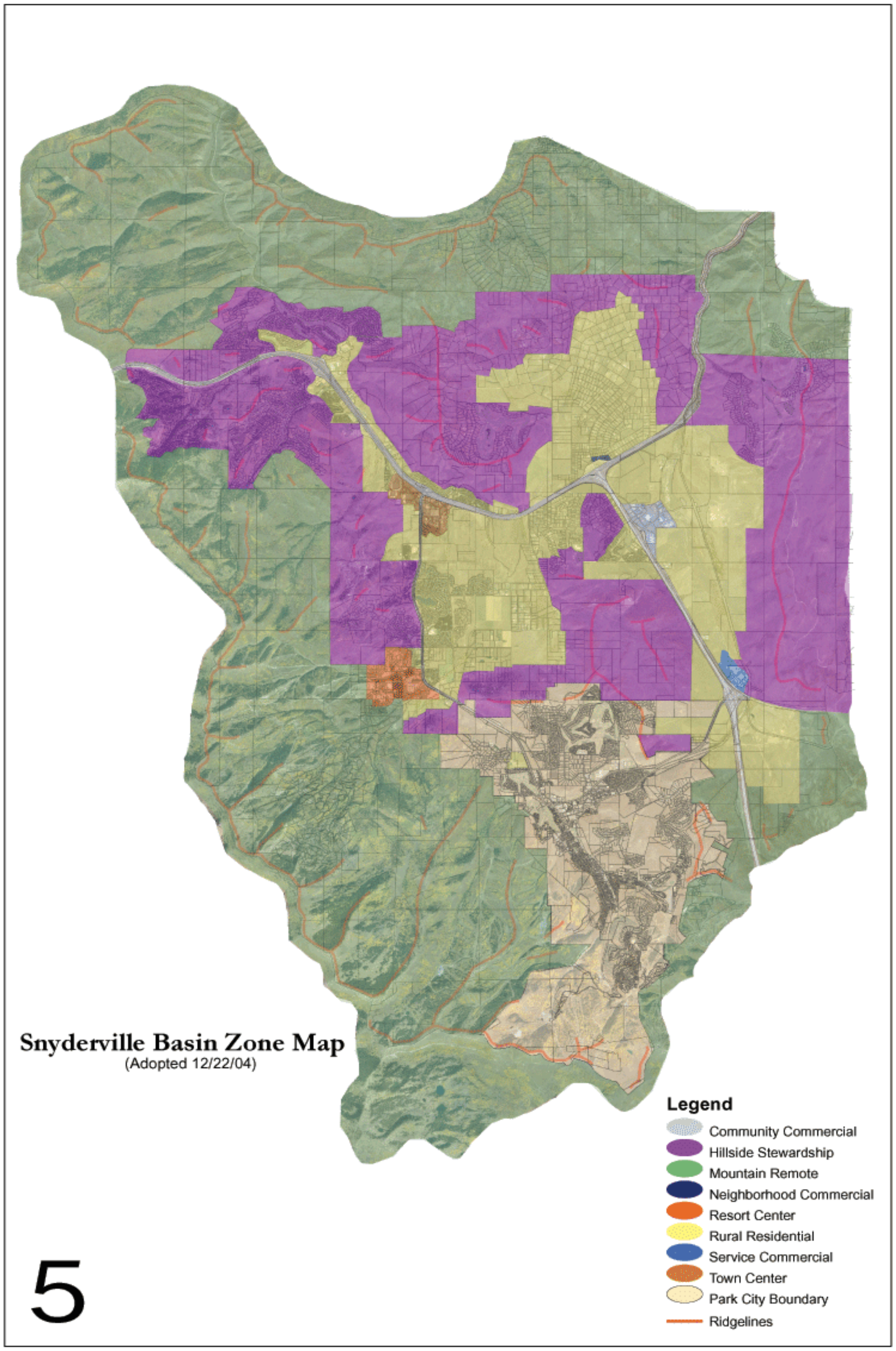

Figure 7.1. Snyderville Basin zoning map (Summit County 2008).

Figure 7.2. Synderville Basin Water Reclamation District (SBWRD) service area.

7.4 TMDL ANALYSIS

7.4.1 CURRENT LOAD SUMMARY AND TMDL

Current loads and TMDL loads, expressed as daily and annual averages, are summarized for East Canyon Reservoir in Table 7.4. Although daily loads are presented in Table 7.4, annual loads are considered to be the most appropriate averaging period for this TMDL. Annual, rather than daily total maximum loads, are the most appropriate for establishing discharge UPDES permits associated with this TMDL. The current total phosphorus load to East Canyon Reservoir is 3,350 kgTP/year (9.2 kgTP/day), including a watershed load of 2,555 kgTP/year (7.0 kgTP/day) and an internal load of 795 kgTP/year (2.2 kgTP/day). The watershed load is currently made up of 483 kgTP/year (1.3 kgTP/day) from the ECWRF and 2,072 kgTP/year 5.7 kgTP/day) from nonpoint sources in the watershed. Results from the East Canyon Reservoir W2 model (see Chapter 5) indicate that attainment of water quality endpoints identified for the waterbody requires a reduction of the total phosphorus load to the reservoir of 730 kgTP/year, which represents an overall reduction of 22% and a total annual phosphorus load of 2,619 kgTP/year. The total annual load corresponds to an average daily load of 7.2 kgTP/day. However, this average could vary with hydrology over the year and is expected to be attained only on average over the course of the year.

Table 7.4 Summary of Maxiumum Total Phosphorus Seasonal and Daily Loads for Attainment of Water Quality Standards in East Canyon Reservoir

	Current Load (2003–2007)		2008 TMDL Load	
	Average Annual (kg/year)	Average Daily (kg/day)	Average Annual (kg/year)	Average Daily (kg/day)
Total Nonpoint Sources	2,072	5.7	1,067	2.9
Total Point Sources (including future growth)	483	1.3	895	2.5
MOS		-	262	0.7
Total Watershed Load	**2,555**	**7.0**	**2,224**	**6.1**
Total Internal Load	**795**	**2.2**	**395**	**1.1**
Total Load To Reservoir	**3,350**	**9.2**	**2,619**	**7.2**

7.4.2 MARGIN OF SAFETY (MOS)

The Clean Water Act requires that the total load capacity "budget" calculated in TMDLs must also include a margin of safety (MOS). The MOS accounts for uncertainty in the loading calculation. The MOS may not be the same for different waterbodies due to differences in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs via the use of conservative assumptions in the load calculation or be specified explicitly as a proportion of the total load. The East Canyon Creek TMDL relies on conservative assumptions to meet the MOS requirement. The most important conservative assumption is the exclusion benefits likely to be observed from sediment reduction (associated with nonpoint source controls required for the phosphorus TMDL in the reservoir) on DO and macrophyte growth in East Canyon Creek. The recommendations for physical changes to the creek (establishing a protected base flow, shading, and bank stabilization) should, according to the HydroQual modeling, attain water quality endpoints. Additional improvement associated with sediment reduction provides a margin of safety associated with the analysis. The East Canyon Reservoir TMDL uses an explicit MOS of 10% or 262 kgTP/year.

7.4.3 Load Allocation and Rationale

The changes in allocated and monitored loads from the pre-TMDL period of the 1990s to the implementation of the 2000 TMDL as well as the allocated loads identified for the revised 2008 TMDL for East Canyon Reservoir are summarized in Table 7.5 and Figure 7.3. The 2000 East Canyon TMDL does not account for internal load in the calculation of total current load to the reservoir or in the load allocation for the TMDL (the load was calculated based on the long term annual yield of the watershed to the reservoir at an average total phosphorus concentration of 0.05 mg/L). This is despite numerous acknowledgements of internal loading contributing to the total reservoir load in the Clean Lakes report, upon which the TMDL based most of its findings (Judd 1999). The exclusion of internal sources in the 2000 TMDL was one of the primary critiques of that TMDL. In response to these critiques, UDWQ has sought to improve the 2000 TMDL by including internal sources in the revised 2008 TMDL. For comparison purposes, an internal load has been estimated for the pre-2000 period by calculating the difference in median concentrations of phosphorus at the dam between the pre-2000 TMDL period and the current TMDL period (2003–2007). It was assumed that the outflow load in pre-2000 is proportional to the change in concentration between the two periods (therefore eliminating hydrologic differences from the calculation). Hydrologic data from the pre-2000 period were not used in this estimate, and therefore these estimates should be used only for purposes of comparing loads and allocations between the two TMDLs. Due to the incorporation of internal load in the 2008 TMDL, the total allocated load to the reservoir requires a 40% reduction from the 2000 allocated loads (assuming an allocation to internal sources of the full estimated load occurring prior to 2000).

Future growth projections for the ECWRF require additional allocation to this source above the allocation identified in the 2000 TMDL (663 kgTP/year). In order to compensate for the required increase identified for the point source in the watershed, a 50% reduction from current loads (2003–2007) of other sources (nonpoint and internal reservoir load) has been identified (Table 7.5). Load allocations (LA) require equal reductions from nonpoint sources and internal reservoir sources. Load allocations are distributed among nonpoint source categories in the implementation plan for East Canyon Reservoir watershed. Recommendations for nonpoint source reductions will include all sources and will be based on effectiveness, attainability, BMPs cost, and the goal of spreading the responsibility for water quality improvement among all stakeholders of the watershed.

Table 7.5. Summary of Current Total Phosphorus Load (kg/year) and Load Allocations Identified for the Revised East Canyon Reservoir TMDL

	2000 TMDL Allocated Load	Current Load (2003–2007)	2008 TMDL Allocated Load	Change from Current Load (2003–2007)		Change from Allocated Load (2000)	
	kg/year	(kg/year)	(kg/year)	(kg/year)	Percent	(kg/year)	Percent
Total Nonpoint Sources	1,857	2,072	1,067	-1,005	-49%	-790	-43%
Nonpoint sources	*1,031*						
Reserved for growth	*825*						
Point sources*	663	483	895	412	85%	232	35%
Margin of safety	42	NA	262	262	NA	220	524%
Total Watershed Load	2,562	2,555	2,224	-331	-13%	-338	-13%
Internal reservoir load	**Not calculated** (Estimated 1,744)**	**795**	**395**	**-400**	**-50%**	**-1,379 (Estimated**)**	**-78% (Estimated**)**
Total Load to Reservoir	**Not calculated** (Estimated 4,336)**	**3,350**	**2,619**	**-731**	**-22%**	**-1,717 (Estimated**)**	**-40% (Estimated**)**

**Including future growth for ECWRF*

*** The 2000 East Canyon TMDL does not account for internal load in the calculation of total current load to the reservoir or in the load allocation for the TMDL. For comparison purposes, an internal load has been estimated for the pre-2000 period by calculating the difference in median concentrations of phosphorus at the dam between the pre-2000 TMDL period and the current TMDL period (2003–2007). It was assumed that the outflow load in pre-2000 is proportional to the change in concentration between the two periods (therefore eliminating hydrologic differences from the calculation). Hydrologic data from the pre-2000 period were not used in this estimate and therefore should be used only for purposes of comparing loads and allocations between the two TMDLs.*

Figure 7.3 summarizes the change in allocated and monitored loads from the pre-TMDL period of the 1990s to the implementation of the 2000 TMDL as well as the allocated loads identified for the current 2008 TMDL for East Canyon Reservoir. Overall, ECWRF has been responsible for all of the reductions observed in East Canyon Creek in recent years. ECWRF continues to operate well below its allocated load from the 2000 TMDL. Internal reservoir sources were not considered in the previous TMDL study, therefore total load estimates prior to the TMDL are likely to be higher than those summarized in this revised TMDL.

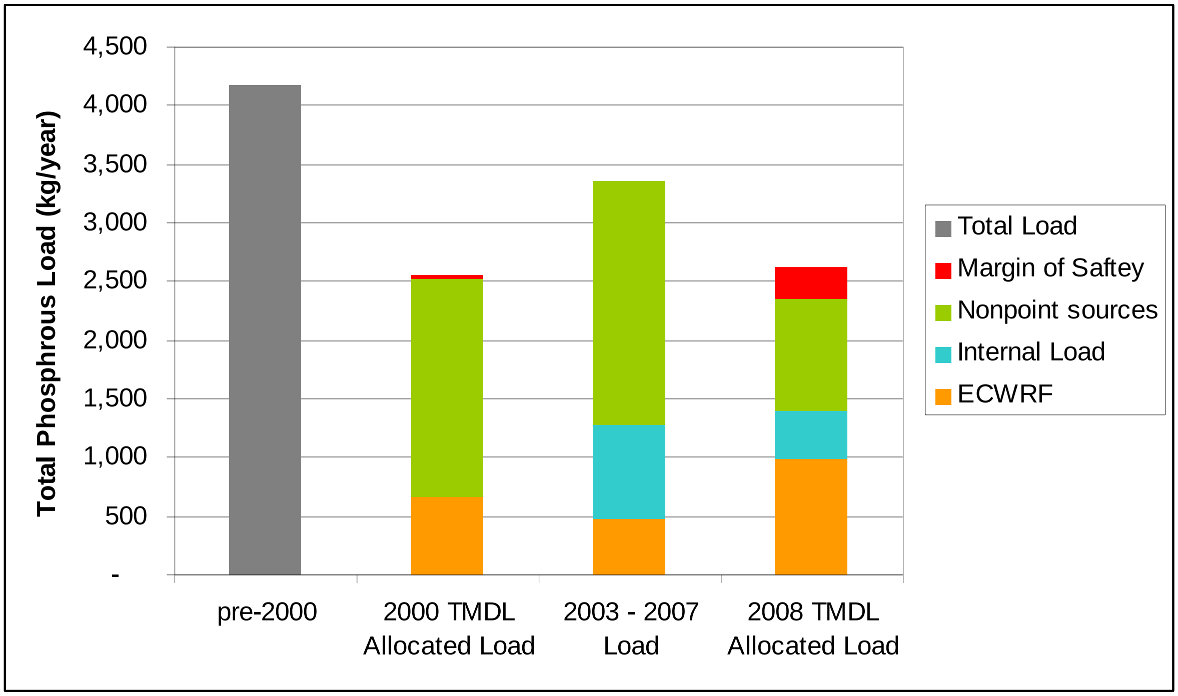

Figure 7.3. Change in total phosphorus load and allocations for the East Canyon Reservoir TMDL.

EPA provides guidance in allocating loads to point and nonpoint sources in TMDLs (EPA 1999). The *Protocol for Developing Nutrient TMDLs* states that dividing the assimilative capacity of a given waterbody among sources should consider the following issues: economics, political considerations, feasibility, equitability, types of sources and management options, public involvement, implementation, limits of technology, and variability in loads and effectiveness of BMPs. All of these have been considered in determining load allocations for the East Canyon Reservoir TMDL. Those that are particularly applicable to the wasteload allocation assigned to ECWRF are limits of technology, feasibility, and economics.

The ECWRF has one of the highest levels of phosphorus treatment of any treatment system in the State of Utah, and their staff is proud of their performance in reducing phosphorus loads to East Canyon Creek, beyond that required by their permit in recent years. In 2007 the average annual effluent concentration was 0.07 mg/L. The low concentrations can be attributed to ECWRF's well-equipped treatment facilities and outstanding management practices. The revised TMDL allocated load for ECWRF of 895 kg/year is based on a 0.09 mg/L permit limit and a flow of 7.2 MGD, which is the projected flow required to accommodate growth in Snyderville Basin over the next 20 to 30 years.

As the ECWRF approaches capacity, consistent attainment of concentrations less than 0.09 mg/L will become more difficult. ECWRF's biological phosphorus (bio-P) removal system relies on the equalization of influent flow to stabilize the food-to-microorganism ratio and to produce the volatile fatty acids necessary for biological phosphorus removal. Consistent attainment is difficult to guarantee due to influent variability and the reduced capacity of the equalization process. The strength, volume, and temperature of the influent wastewater to the system are highly variable due to the seasonality of the resort community served and the high elevation climate of the area. Although the biological phosphorus removal system is relatively stable, significant shifts in flow and strength can jeopardize consistent attainment of concentrations below 0.09 mg/L. Finally, analytical variability at concentrations below 0.1 mg/L TP increases as concentration decreases. The margin-of-error of the analyses can overwhelm the perceived 'actual' result as attempts are made to measure concentrations at very low levels. For these reasons, allocation of a load less than 895 kg/year would result in a higher likelihood of permit exceedance. Exceedance of a permit limit based on a 0.05 mg/L would be almost guaranteed for the system, and exceedance of a limit based on 0.07 mg/L would be highly likely (personal communication between Michael Boyle, SBWRD and Erica Gaddis, SWCA, April 2, 2009).

The use of chemicals is a fundamental component in maintaining the ECWRF average annual concentrations. The chemical phosphorous removal system at the end of the treatment train relies on the optimal mixing of precise amounts of alum and polymer with secondary effluent to ensure the dissolved phosphorus is extracted from the solution. If the mixing process is upset, time would be required to resume optimal chemical phosphorus removal and thus reach the required concentration limit. Further, meeting a concentration limit below 0.09 mg/L would require additional chemical use. The increase in chemicals required to reduce total phosphorus below 0.09 mg/L is non-linear and increases dramatically at each incremental reduction in total phosphorus. This results in significantly more chemical sludge production, which requires hauling and disposal resulting in a significant increase in the waste and carbon footprint of the system. The cost of solids handling and disposal to reduce total phosphorus concentration from 0.09 mg/L to 0.05 mg/L is estimated to be $26,000 per MGD treated. At full capacity, this would represent an additional $187,200 in annual operating costs for the system.

This TMDL has been developed as a phased TMDL in recognition of revisions to assessment methodology by UDWQ that are currently underway. During the first ten-year phase of the TMDL, nonpoint source implementation is expected to achieve water quality targets and to offset the increased load allocated to ECWRF. If water quality targets have not been achieved by 2019, UDWQ will reevaluate the East Canyon Reservoir TMDL and consider the following additional steps:

- Use Attainability Analysis
- Site-specific water quality standards
- examination of other causative factors of the low DO water quality impairment such as water management or organic matter loading

These steps would only be taken after nonpoint source reduction projects have been fully implemented. At this point, further phosphorus reductions would be difficult to attain due to the high background load of phosphorus in the watershed associated with naturally occurring phosphatic shales. If nonpoint source projects have not been fully implemented by 2019, a formal water quality trading program would be considered.

7.5 SEASONALITY

There are two important temporal aspects to the East Canyon Reservoir TMDL: the distribution of phosphorus load across hydrologic periods, and the availability of phosphorus for algal growth during different seasons.

The phosphorus loads from the ECWRF tend to increase during the wintertime recreation season when the population of the watershed increases. Efforts to reduce tributary loads become more of a challenge during the winter months as temporary increases in population provide additional challenges to the naturally occurring processes that occur in the watershed. Fortunately, these peak loading events do not occur during the critical algal growth season. The current permit for ECWRF includes a concentration limit of 0.1 mg/L during the summer months of July, August, and September. Although this seasonal component of the permit was based on the 2001 East Canyon Creek TMDL, it is also protective of the reservoir during the summer seasons when stratified conditions result in direct discharge of tributary dissolved phosphorus to the epilimnion where algal blooms occur.

The distribution of phosphorus load varies considerable with hydrologic events. Spring melt and rain-on-snow events in early spring deliver the majority of the nonpoint source phosphorus load to East Canyon Reservoir. Following stratification during the summer anoxic conditions result in the release of iron-bound phosphorus from sediments. Most of this phosphorus originated in the watershed during the previous year, although some phosphorus represents a historic legacy. Load from the wastewater treatment plant is relatively constant across the year with peak loads occurring during the winter season when tourism related to winter recreation peaks in the area.

Phosphorus is delivered to the photic zone through three different processes: tributary flow directly to the epilimnion, sediment release and diffusion up to the epilimnion, and mixing of the water column during fall turnover. Each of these processes dominates delivery of phosphorus to the epilimnion during different times of the year. Phosphorus contained in spring runoff provides the primary source of phosphorus for algal blooms in the spring and early summer. Most of the nutrients released from sediments in the summer are physically unavailable below the strong thermocline. However, the chilling of the thermocline induces the beginning of fall turnover, and phosphorus is replenished by mixing from deeper layers to the shallow portions of the reservoir. Algal biomass can increase very quickly in the fall, especially if a long period of relatively warm weather follows the first fall chill and turnover.

Therefore, efforts to reduce tributary loads to East Canyon Reservoir should focus on nonpoint source runoff during the spring melt period. Efforts to minimize internal sources of phosphorus should be focused on late summer and early fall.

7.6 SUMMARY

This document represents the revised TMDL analysis for East Canyon Reservoir and East Canyon Creek in north-central Utah. The watershed drains 145 square miles that includes Park City, several major ski resorts, and a portion of Snyderville Basin from the Morgan–Summit county line to the headwaters of East Canyon Creek. The lands in the watershed are almost entirely privately owned. The reservoir shoreline is owned by the State of Utah with unrestricted public access to East Canyon State Park on the eastern side of the reservoir, and restricted vehicle access to the west side of the reservoir. The historical agricultural irrigation use of water has decreased in recent years with a corresponding increase in culinary water use due to increasing population growth, recreation use, and development in the watershed.

The overall goal of the TMDL process is to restore and maintain water quality in East Canyon Reservoir and Creek to a level that protects and supports the designated beneficial uses (domestic water use, primary and secondary contact recreation, cold water game fish, and agricultural water supply). The cold water game fish designated use (3A) was identified as partially supported on the State of Utah 1998

303(d) list (UDEQ 2000a). This led to the development of a TMDL for East Canyon Reservoir in 2000. Since 2000 the only point source in the watershed, the East Canyon Water Reclamation Facility, has reduced nutrient loads to East Canyon Creek significantly. In addition, BMPs have been implemented to reduce nutrient runoff from nonpoint sources throughout the watershed. Load reduction efforts have been reflected in improved water quality in East Canyon Reservoir.

Population in the study area is projected to increase from approximately 24,000 in 2001 to approximately 64,000 in 2030 and to 86,000 by the year 2050. New residential and commercial development in the Snyderville Basin will require additional connections to the East Canyon Water Reclamation Facility (ECWRF). Accommodation of the expected population growth in the basin will require expansion of the treatment system to an average discharge of 7.2 MGD. The expanded treatment system will be designed such that the concentration of nutrients will remain low, as they are today, with projected average total and dissolved phosphorus concentrations of 0.10 and 0.03 mg/L, respectively. Nonpoint sources of pollutants include urban runoff, streambank erosion, agricultural land use, residential and commercial development, and stormwater. Additional phosphorus sources in the watershed consist of naturally occurring phosphatic shales of the Phosphoria Formation located in the southeastern and southwestern portions of the watershed, and phosphorus loading from reservoir sediments due to anoxic conditions.

7.6.1 East Canyon Reservoir

Water quality endpoints identified for the revised East Canyon Reservoir TMDL aim to improve conditions for the cold water fishery beneficial use while also protecting recreational uses of the reservoir. The DO endpoints identified for the reservoir are consistent with existing State Water Quality criteria and were developed in collaboration with the Utah Division of Wildlife Resources. During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20^{o}C shall be maintained in a 2 meter layer across the reservoir to provide adequate refuge for cold water game fish. These criteria were determined to provide sufficient support for the cold water game fish beneficial use (3A) designated by the State of Utah for East Canyon Reservoir. Macrophyte- and algae-related water quality endpoints were selected to reduce the direct and indirect influence of decomposition associated with degradation of algal bloom biomass on DO concentrations and for the protection of recreational beneficial uses. Three algal related endpoints were identified for East Canyon Reservoir: a mean seasonal chlorophyll *a* value of 8.0 μg/L (based on a mean TSI value of less than 50); chlorophyll *a* concentrations not to exceed a nuisance threshold of 30 μg/L more than 10% of the season; and to maintain dominance by algal species other than blue-green algae. A reservoir model (CE-QUAL-W2) was developed to correlate DO and algal related endpoints to total phosphorus, as well as to describe reservoir dynamics related to seasonality of observed impairments and reservoir dynamics. Attainment of the DO endpoints specific to East Canyon Reservoir correlate with mean seasonal total and dissolved phosphorus concentrations of 0.03 mg/L and 0.02 mg/L, respectively. These concentrations are also predicted to be sufficient to meet all of the algal related endpoints.

The current total phosphorus load to East Canyon Reservoir is 3,350 kgTP/year (9.2 kgTP/day), including a watershed load of 2,555 kgTP/year (7.0 kgTP/day) and an internal load of 795 kgTP/year (2.2 kgTP/day). The watershed load is currently made up of 483 kgTP/year (1.3 kgTP/day) from the ECWRF and 2,072 kgTP/year from nonpoint sources in the watershed. Results from the East Canyon Reservoir W2 model indicate that attainment of reservoir water quality endpoints requires a reduction of the total phosphorus load to the reservoir of 730 kgTP/year, which represents an overall reduction of 22% and a total annual phosphorus load of 2,619 kgTP/year. The total annual load corresponds to an average daily load of 7.2 kgTP/day. However, this average could vary with hydrology over the year and is expected to be attained only on average over the course of year. In addition, future growth projections for the ECWRF require additional allocation to this source above the allocation identified in the 2000 TMDL (663 kgTP/year). To compensate for the required increase identified for this point source, a 50% reduction of other sources (nonpoint and internal reservoir load) has been identified. The East Canyon Reservoir Project Implementation Plan (PIP) that accompanies this TMDL provides reasonable assurance that these load reductions can be attained through implementation of BMPs throughout the watershed in addition to in-reservoir treatments. The PIP identifies land use specific BMPs, priority subbasins for implementation, a time frame for implementation, a coordination plan, a monitoring plan, and unit costs associated with recommended structural BMPs.

7.6.2 EAST CANYON CREEK

The primary impairment on East Canyon Creek relates to low nocturnal DO caused by respiration of macrophytes and periphyton. The 2000 TMDL had assumed that excess macrophyte and periphyton growth was driven primarily by excessive nutrients (principally phosphorus) in the water column (UDEQ 2000b). Phosphorus reductions were intended to produce significant reductions in nuisance macrophyte and/or algal growth that impair water quality and stream habitat. However, implementation of the 2000 TMDL does not appear to have reduced macrophyte and periphyton biomass. Baker et al. (2008) and HydroQual (SBWRD 2008) determined that the overabundance of aquatic macrophytes in the creek is currently driven by sediment accumulation, widened channel conditions, shallow water levels, low streamflow during the summer, and a lack of stream shading. Phosphorus concentrations were not identified as a controlling factor in algae and macrophyte densities.

Results of scenario modeling for East Canyon Creek indicate that the DO endpoint of 4.0 mg/L as a daily minimum would be achieved, even during the worst month (August), with a 25% reduction in photosynthetic rate (P_{max}) or an increase in flow of 5 cfs. The former can be reasonably achieved through riparian plantings that achieve 50% shade of the creek and through the establishment of a protected base flow, both of which are being actively pursued in the watershed to address the latter. The East Canyon Creek PIP that accompanies this TMDL identifies priority reaches for riparian planting, streambank stabilization, and establishment of a protected base flow. The PIP also includes a time frame for implementation, a coordination plan, a monitoring plan, and costs associated with the project.