Point and non-point sources of nitrogen in the Bear River Basin

Term project paper – Jonna van Opstal

1. Introduction

The Bear River Basin is a large, extensive watershed located in three different states: Utah, Wyoming and Idaho. The Bear River encompasses 6 HUC8's and is 491 miles long, which makes it the longest river in the USA that does not terminate in the sea.
A downstream irrigation system in the Tremonton (Northern Utah) area is part of a research project determining water quantity and quality issues. The irrigation water is supplied by the Bear River at an off-take from Cutler Dam. It is essential to achieve insight on the river basin as a whole to understand the water quality characteristics downstream. Management of water quality in this watershed requires therefore a holistic approach. Determining the sources of nitrogen loading to the surface water can enhance a better management strategy for the area and the entire basin.
This research paper elaborates on the objectives, methodology, results and analysis of this term project.

2. Objective

The objective of this term project is (1) to create a holistic dataset of the Bear River Basin focusing on water quality issues of this watershed and (2) to determine the point and non-point sources contributing to nitrogen loading in the streams.

3. Methodology

This project divided the work in a 4 step plan, to achieve the duel objectives mentioned previously. The steps are schematically summarized in figure 1.

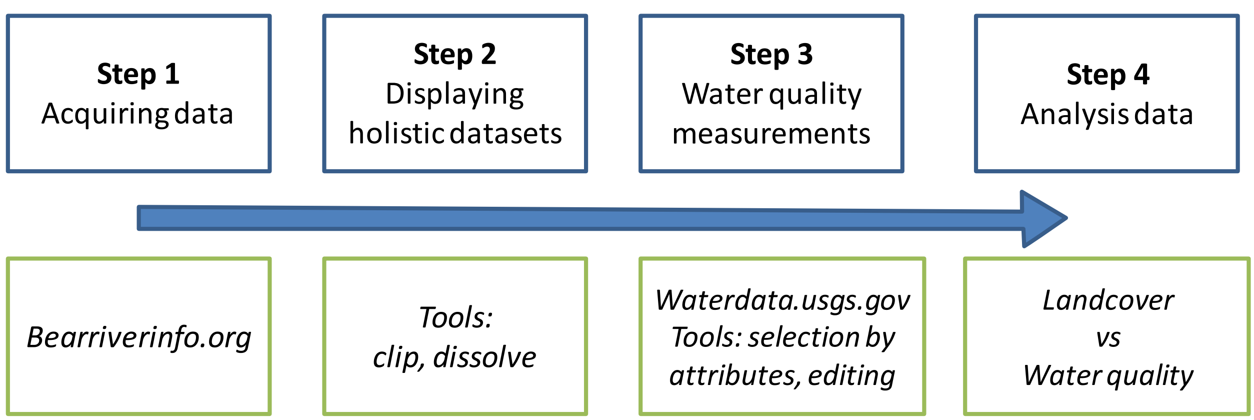

Figure 1 **Methodology according to a 4 step plan**

1. The first step for this term project was to acquire different datasets, which can form a basemap of the area with general information on the watershed. Several datasets could be downloaded

from an online site focusing only on the Bear River Basin[1]. The acquired datasets relevant for this study are shown in table 1 and are presented in figure 2.

Table 1 Datasets for basemap of the Bear River Watershed

Data	Feature/Raster	Source	Scale
Flowlines	Polylines	USGS – NHD	1:100,000
Waterbodies	Polygons	USGS – NHD	1:100,000
Basin and HUC8 borders	Polygons	EMRG	1:24,000
Dam locations	Points	USEPA BASINS	1:500,000
Landcover	Polygons	USEPA BASINS	1:250,000
Elevation DEM, 30m	Raster	USGS Seamless Data	1:24,000
Water quality stations	Points	USEPA BASINS	
TMDL 303(d) streams, rivers	Polylines	Cirrus Ecological Solutions Inc.	1:24,000
TMDL 303(d) lakes	Polygons	Cirrus Ecological Solutions Inc.	1:24,000
TMDL 303(d) point sources	Points	Cirrus Ecological Solutions Inc.	1:24,000

2. The holistic dataset is displayed on the scale of the basin to have an overview of the entire Bear River area. All datasets were clipped using the basin boundary shape file as shown in figure 2.

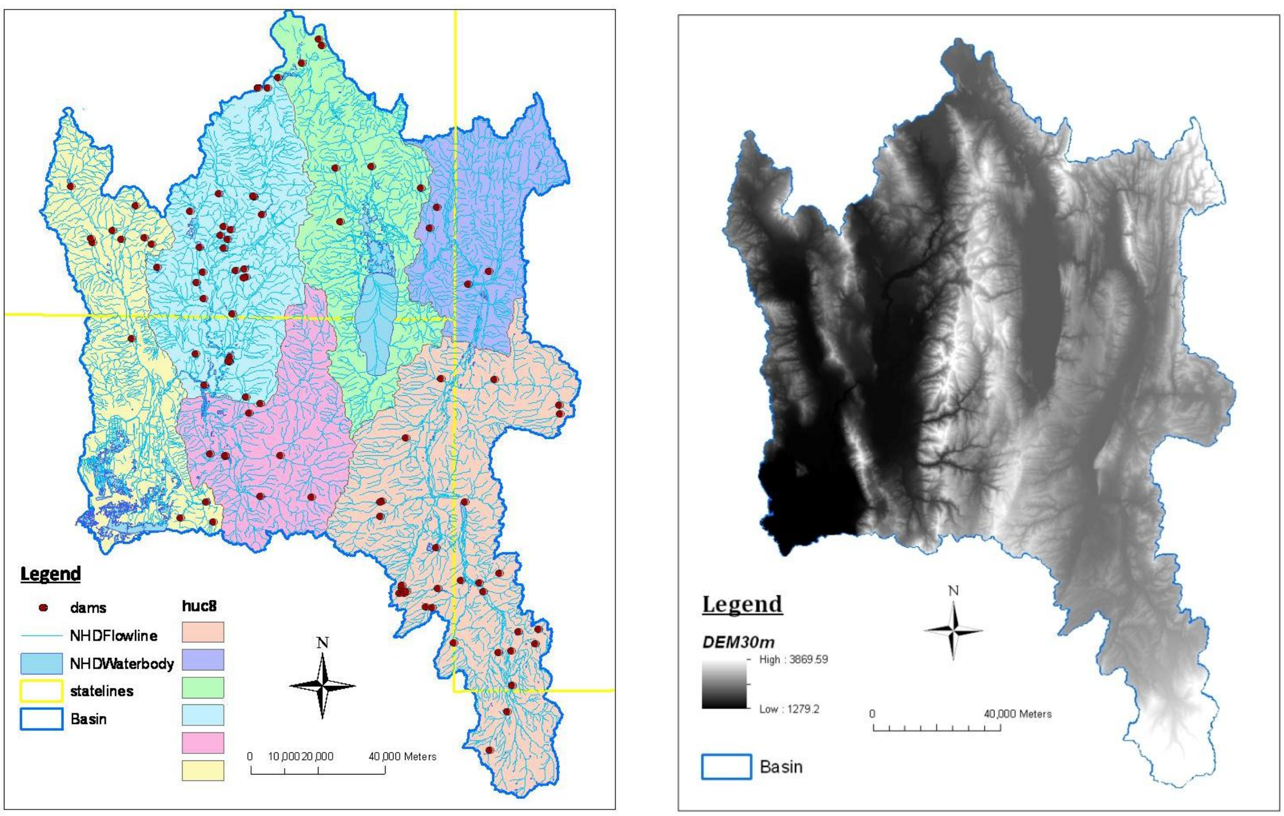

Figure 2 Basemaps for the Bear River Basin: HUC8's and DEM

[1] http://bearriverinfo.org

Additionally, some datasets were transformed for further analysis. The landcover dataset was provided in polygons, whilst it was useful for the next steps to convert this to a raster dataset. The conversion was easily performed with the 'feature to raster' GIS tool.
Furthermore, the DEM dataset was used for the watershed delineation. The GIS tools for a watershed delineation were introduced in exercise 4. The tools can be found in the Spatial Analyst>Hydrology toolbox. The sequence of performing the water delineation is listed below. During the process it was ensured that all the raster datasets had the same grid size (30 meters) and were snapped with the original DEM dataset.

1. DEM reconditioning
2. Pit filling
3. Flow direction
4. Flow accumulation
5. Determining outlet of watershed
6. Delineating watershed
7. Streams and streamlinks
8. Delineating subcatchments
9. Converting raster data (catchment, drainageline) to features
10. Use feature vertices to points tools
11. Develop stream network

3. The next step was to achieve data on water quality measurements in the area. The location of the water quality measurement stations in the Bear River basin was downloaded as a GIS dataset. This total number of stations in the basin is 580. It was therefore important to make a selection to reduce this to a reasonable number for further analysis.
Water quality was measured with water samples and recorded on the USGS-NWIS site[2]. On this site it was possible to search with a text file with a collection of site ID numbers. This text file was achieved through exporting the attribute table of the water quality stations dataset.
Performing this search gave a reduced number of stations. Eventually a selection of 12 stations was made, which all had data from the last decade and had a consistency in parameters measured. Table 2 presents the 12 stations selected with further information.

Table 2 Selection of water quality stations

SiteID	Location	HUC8
10011500	BEAR RIVER NEAR UTAH-WYOMING STATE LINE	16010101
10020100	BEAR RIVER ABOVE RESERVOIR NEAR WOODRUFF, UTAH	16010101
10020300	BEAR RIVER BEL RESV. NR. WOODRUFF UTAH	16010101
10028500	BEAR RIV BEL PIXLEY DAM NR COKEVILLE WYO	16010102
10038000	BEAR RIVER BL SMITHS FORK NR COKEVILLE, WYOMING	16010102
10039500	BEAR R AT BORDER WY	16010102
10068500	BEAR RIVER AT PESCADERO, IDAHO	16010201
10079500	BEAR RIVER AT ALEXANDER IDAHO	16010202
10092700	BEAR RIVER AT IDAHO UTAH STATE LINE	16010202
10118000	BEAR RIV NR COLLINSTON UTAH	16010204
10126000	BEAR R NR CORINNE	16010204
10115200	LOGAN RIVER BLW BLACKSMITH FORK NR LOGAN, UTAH	16010203

[2] http://waterdata.usgs.gov/nwis

4. In the fourth step the datasets were analyzed and compared.
   Firstly, the landcover set was used to determine the area per subcatchment. The data needed to be reclassified with agriculture having the value 1 and all other landcover classes having no data values. This selects only the grid cells with agriculture assuming that this is the major contributor to nitrogen loading.
   Using the zonal statistics tool, the sum of cells for agriculture per subcatchment was found. A simple calculation was performed with raster calculator to calculate the fraction of agricultural area per subcatchment:

   $$\frac{number\ of\ grid\ cells\ as\ agriculture}{total\ number\ of\ cells} = \text{fraction of agricultural area per subcatchment}$$

   The area is converted to an area in hectares, which is used for calculating the nitrogen loading for the whole subcatchment.

4. Impaired rivers and streams

Rivers and streams that are polluted with certain high concentrations of nutrients or other chemicals, are called impaired. The concentrations are compared with the standards of the state. As an example, Utah State[3] sets their water quality standard at 4 mg/L NO_3-N (nitrogen in nitrate) and 0.05 mg/L phosphorus.

For this project the dataset for 303(d) impaired rivers, streams and lakes are an indication of low water quality. In figure 3 these datasets are displayed, showing the Bear River, the major river in this basin is impaired. Additionally other streams and some lakes are classified as impaired.

[3] *UAC R317-2*

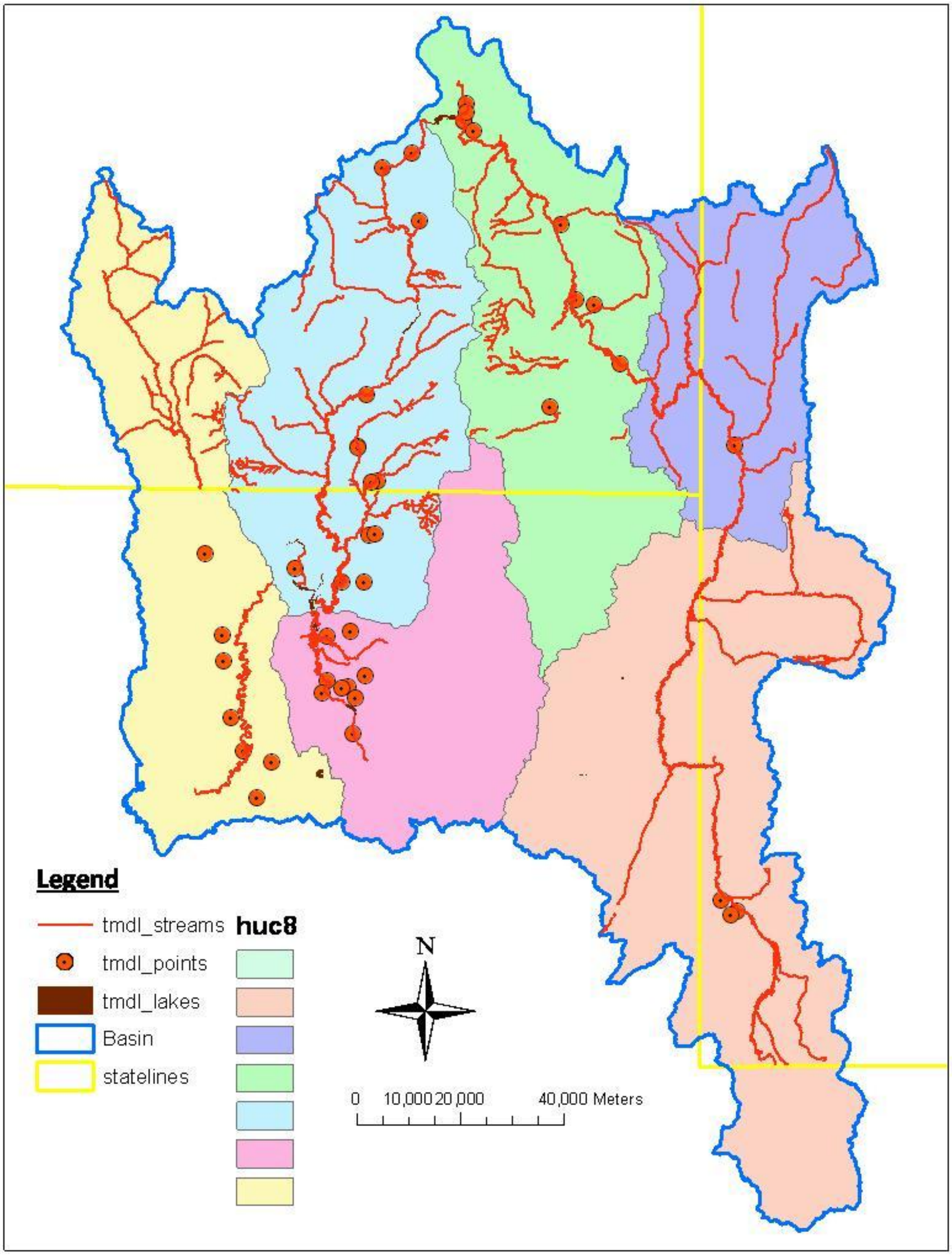

Figure 3 Layout of the Bear River Basin with the impaired streams, lakes and points indicated

Water quality measurements

The water quality measurements from USGS stations were limited in the amount of data available. For a good comparison, the same parameters and month of year were chosen. Two measurements were compared: spring (March) and summer (August) of 2001. In table 3 the findings are presented for total nitrogen concentration and streamflow. With this information the nitrogen load in the river at the location of the measurement station can be estimated. Figure 4 displays the location of the measurements, indicating a higher N concentration downstream of the Bear River.

Table 3 Selection of water quality stations and measurements reported for total nitrogen (TN) in March and August of 2001; shaded cells indicate no data

SiteID	Location	TN_2001_3 [mg/L]	[cfs]	[L/d]	N load [mg/d]	TN_2001_8 [mg/L]	[cfs]	[L/d]	N load [mg/d]
10011500	BEAR RIVER NEAR UTAH-WYOMING STATE LINE	0.19	42	103	19.5	0.21	50	122	25.7
10020100	BEAR RIVER ABOVE RESERVOIR NEAR WOODRUFF, UTAH	1.6	100	245	391.4	0.63	0.53	1	0.8
10020300	BEAR RIVER BEL RESV. NR. WOODRUFF UTAH	0.55	31	76	41.7	1.1	17	42	45.7
10028500	BEAR RIV BEL PIXLEY DAM NR COKEVILLE WYO	0.5				0.73	9.6	23	17.1
10038000	BEAR RIVER BL SMITHS FORK NR COKEVILLE, WYOMING	0.33	160	391	129.2	0.35	110	269	94.2
10039500	BEAR R AT BORDER WY	0.33	150	367	121.1	0.24	82	201	48.1
10068500	BEAR RIVER AT PESCADERO, IDAHO	0.82	108	264	216.7	0.47	1270	3107	1460.3
10079500	BEAR RIVER AT ALEXANDER IDAHO	1.5				0.48			
10092700	BEAR RIVER AT IDAHO UTAH STATE LINE	1.8	389	952	1713.0	0.6	899	2199	1319.6
10118000	BEAR RIV NR COLLINSTON UTAH	2.8				0.69			
10126000	BEAR R NR CORINNE	2.4	1810	4428	10627.2				
10115200	LOGAN RIVER BLW BLACKSMITH FORK NR LOGAN, UTAH	0.53				0.58			

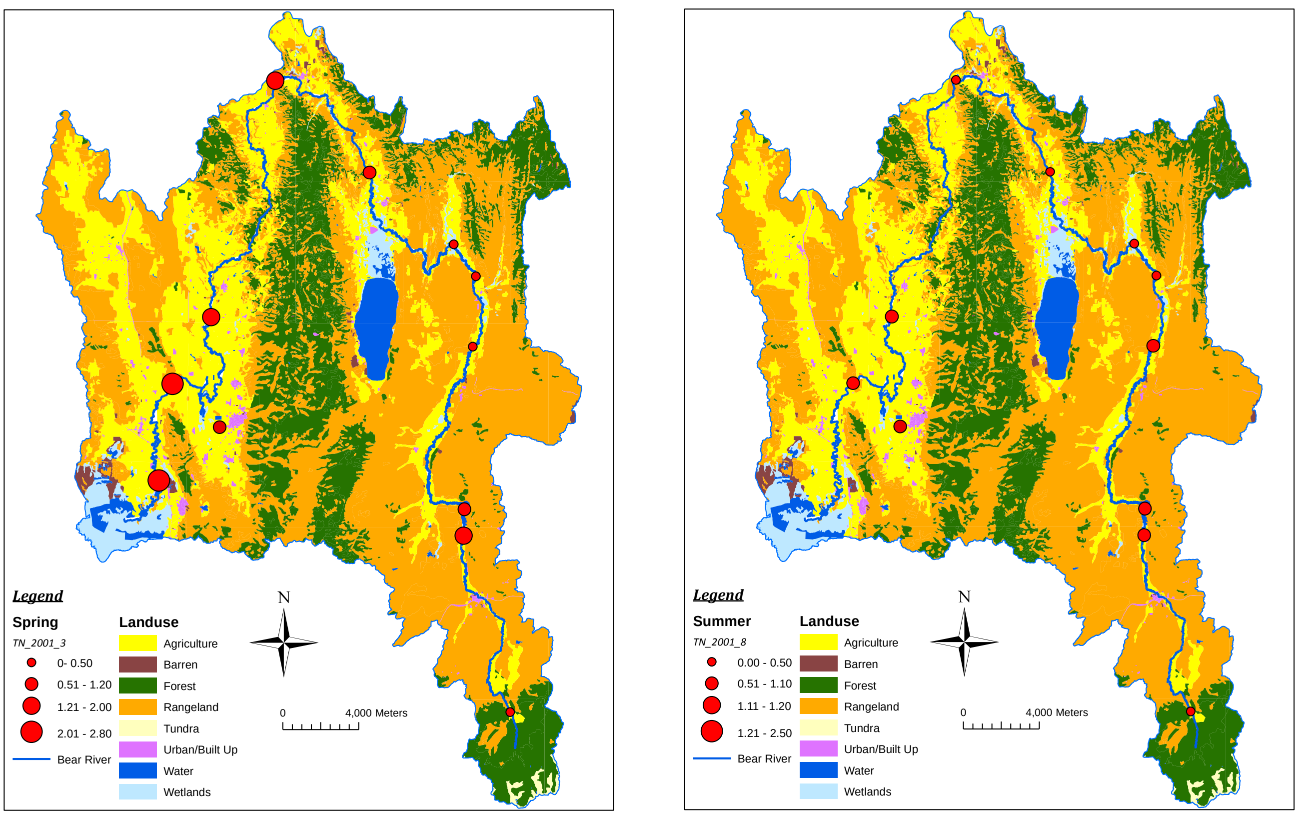

Figure 4 Nitrogen concentration at different measurement locations in the Bear River Basin for spring and summer 2001

5. Nonpoint sources of N loading

Agriculture is known to be the major non-point source of nitrogen in surface water. Fertilizers applied for increasing crop production are part of the runoff after a rainfall event. In the Bear River Basin, agriculture plays a major role. The landcover dataset indicates that large areas are under agricultural activity. In figure 5 the area of each landcover class is displayed showing that rangeland, forest and agriculture are the largest.

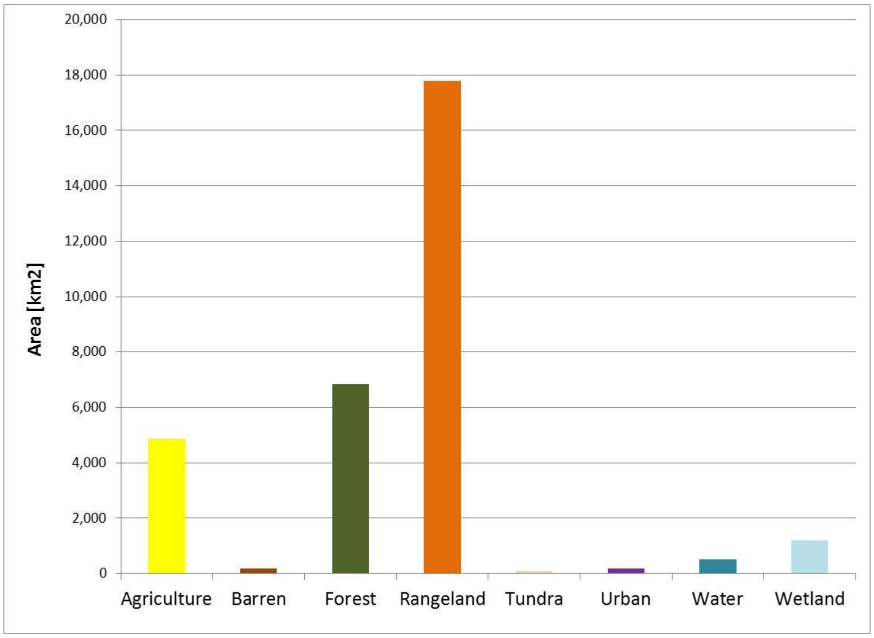

Figure 5 Total area of each landcover class for the Bear River Basin

For each subcatchment the fraction of agriculture is calculated using the GIS tools. In figure 6 the area of agriculture in 30 meter grid cells and the fraction of agricultural area are shown. This figure indicates that downstream of the Bear River the fraction of agricultural area in the subcatchments is larger. Especially the subcatchments close to the river is intensely cultivated.

An indication for nitrogen loading is calculated in figure 7, using a quantity of 4 kg per hectare of agricultural area. This is an indication, however in practice several factors influence the amount of runoff and nitrogen loading for instance soil texture and fertilizer management.

The layout in figure 8 shows the nitrogen loading from agricultural runoff with the overlay from the water measurements at different station locations. It shows that the downstream N loading pattern coincides with those from subcatchments.

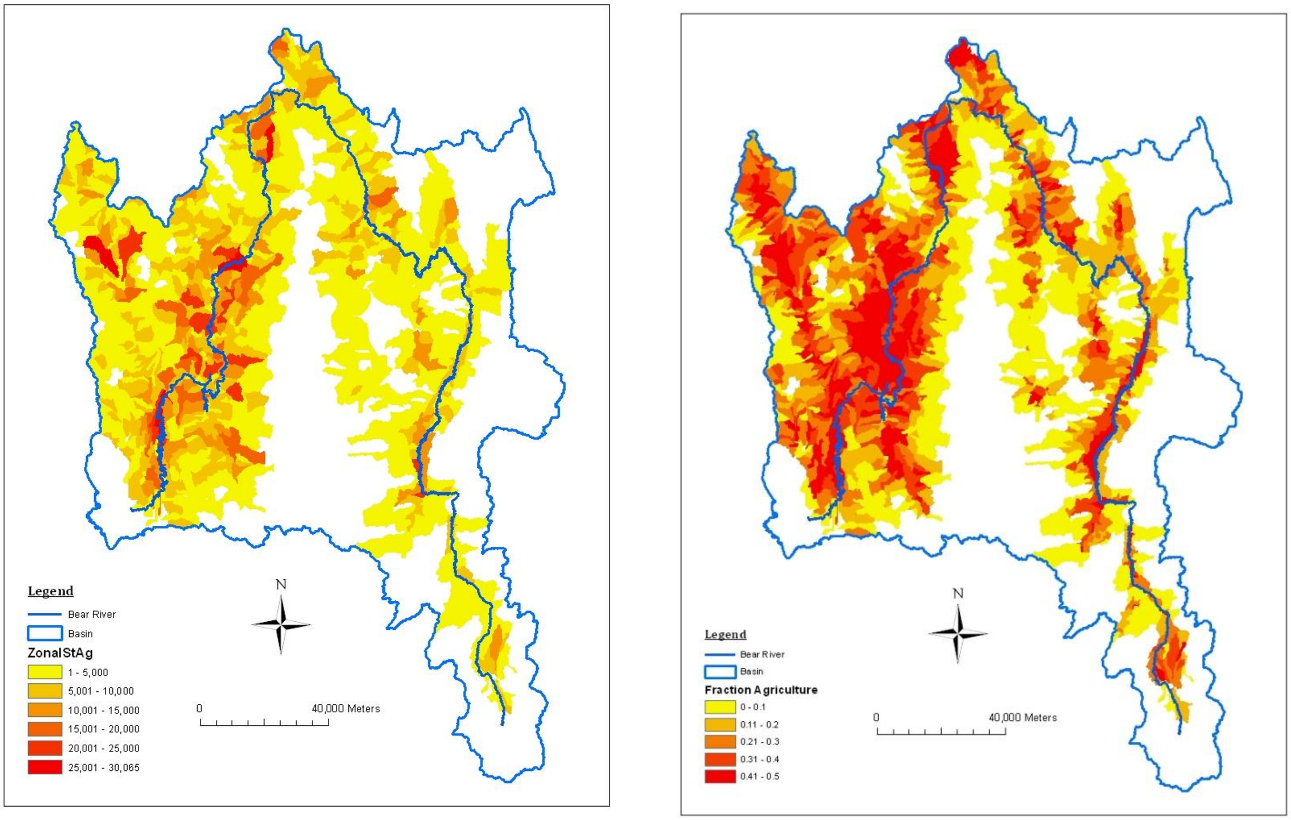

Figure 6 Agricultural area in grid cells and fraction of agricultural area per subcatchment

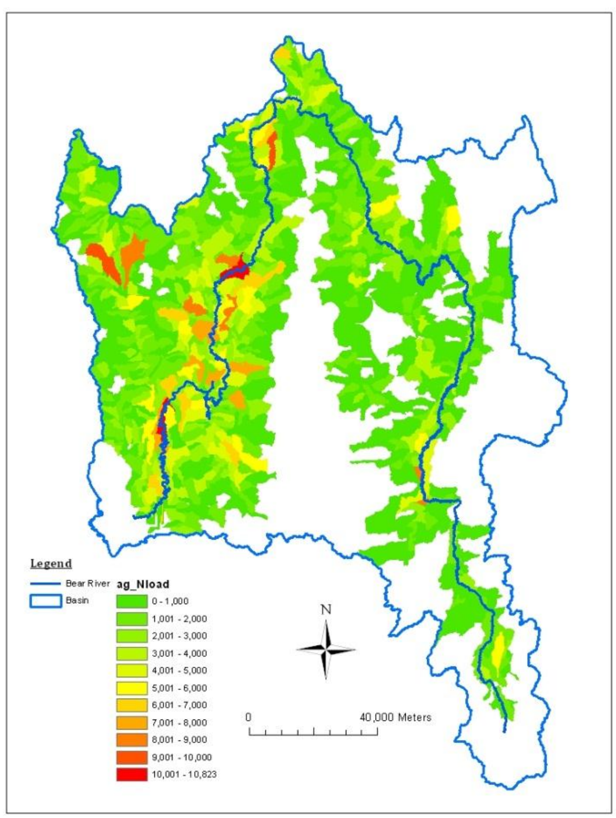

Figure 7 Nitrogen loading through agricultural runoff with 4 kg N per hectare

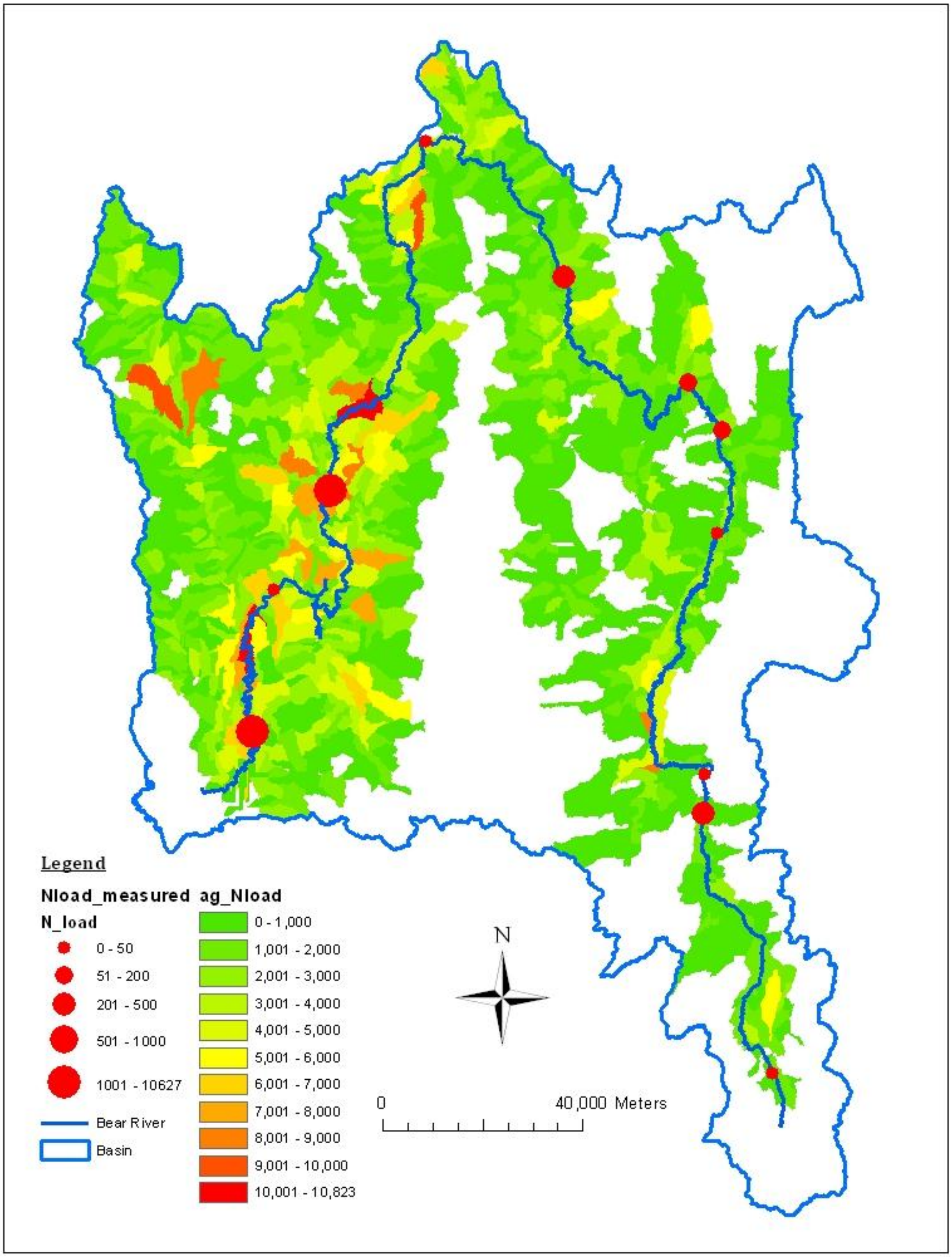

Figure 8 **Comparison between N loading calculated through agricultural runoff and N measured at stations**

6. Point sources of N loading

The locations of the point sources polluting surface water in the Bear River Basin are indicated in figure 9. These point sources consist of water treatment plants and industries. The dataset provided gives a general list, without making a distinction between nitrogen pollution (in the form of nitrate/ammonia) and the pollution by other chemicals. Table 4 gives a list of the point sources including a description. For only three point sources, information was found on high nitrogen loading in the form of ammonia.

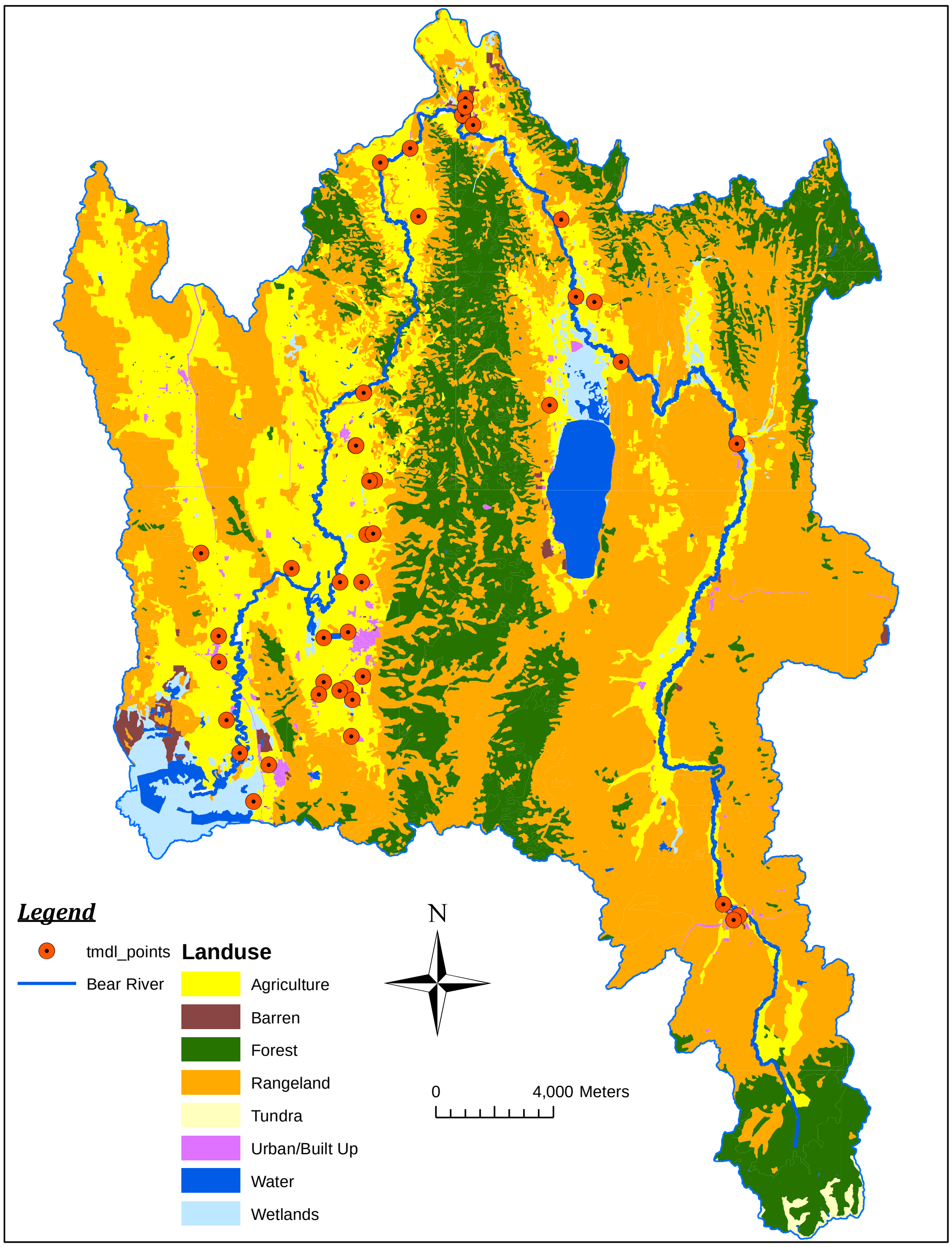

Figure 9 **Location in the Bear River Basin of the point sources causing the pollution of rivers and streams**

Table 4 List of point sources in the Bear River Basin including a description and 3 sites causing high nitrogen loading to the surface water

POINTS_ID	STATE	HUC	NAME	RECEIVING_	DESCRIPTION	total waste load allocation	total load allocation	unit
ID0001180	ID	16010202	DEL MONTE CORP	CUB RIVER	PLANT #130			
ID0001198	ID	16010201	P4 PRODUCTION LLC	SODA CREEK	P4 PRODUCTION, LLC			
ID0001201	ID	16010201	CLEAR SPRINGS FOODS INC	BEAR RIVER VIA BIG SPRING CRK	Big Springs Creek an undetermined distance below Clear Springs Foods Inc.			
ID0001210	ID	16010202	ID-FISH & GAME	Whiskey Creek	Whiskey Creek an undetermined distance below Grace Fish Hatchery			
ID0020214	ID	16010202	PRESTON, CITY OF	Worm Creek	Worm Creek an undetermined distance below Preston City WWTP			
ID0020818	ID	16010201	SODA SPRINGS, CITY OF	Bear River	Bear River an undetermined distance below Soda Springs WWTP			
ID0023825	ID	16010202	GRACE, CITY OF	Bear River Reservoir	Grace City Corp at Bear River Reservoir			
ID0025143	ID	16010201	GEORGETOWN, CITY OF	BEAR RIVER	GEORGETOWN, CITY OF			
ID0025569	ID	16010202	FRANKLIN, CITY OF	Cub River	Cub River an undetermined distance below City of Franklin WWTP			
ID0025585	ID	16010201	MONTPELIER, CITY OF	Bear River	Bear River an undetermined distance below City of Montpelier WWTP			
ID0025666	ID	16010201	SCHOOL DISTRICT 150	SODA SPRINGS (SODA CREEK)	SCHOOL DISTRICT 150			
ID0026085	ID	16010202	RIVERDALE RESORT	BEAR LAKE RIVER	RIVERDALE RESORT			
ID0026948	ID	16010201	AQUA WEST INC	SPRING CREEK	BEAR LAKE FISH FARM			
ID0027138	ID	16010201	LE GRAND JOHNSON CONSTRUCTIO	BEAR RIVER	LE GRAND JOHNSON CONSTRUCTION			
ID0027472	ID	16010201	KERR-MCGEE CHEMICAL CORP	BEAR RIVER	KERR-MCGEE CHEMICAL CORP			
ID0027481	ID	16010201	MONTPELIER MIDDLE SCHOOL	MONTPELIER CREEK	MONTPELIER MIDDLE SCHOOL			
ID0027839	ID	16010202	FRANKLIN CO DAYTON LANDFILL	Not available	FRANKLIN CO DAYTON LANDFILL			
IDG130113	ID	16010202	Bear River Trout Farm	Bear River	Bear River an undetermined distance below Bear River Trout Farm			
UT0000264	UT	16010202	WESTERN DAIRYMEN'S (CACHE VLY	Not available	WESTERN DAIRYMEN'S (CACHE VLY			
UT0000281	UT	16010203	MILLER-E A, INC	Ditch - Spring Creek	Discharge stream from EA Miller Inc an undetermined distance down a ditch to Spring Creek			
UT0000469	UT	16010202	WESTERN DAIRYMANS COOP INC	Not available	WESTERN DAIRYMANS COOP			
UT0000604	UT	16010204	U & I INC	Not available	U & I INC			
UT0020371	UT	16010203	Wellsville City Corporation	Little Bear River	Little Bear River an undetermined distnace below Wellsville City Corp.	38.2	1.1	lbs/day ammonia
UT0020303	UT	16010204	TREMONTON CITY CORP	Malad River	Malad River an undetermined distance below Tremonton City Corp			
UT0020311	UT	16010204	BEAR RIVER- TOWN OF	Malad River	Malad River an undetermined distance below Town of Bear River WWTP			
UT0020907	UT	16010202	RICHMOND- CITY OF	Cub River	Cub River an undetermined distance below City of Richmond WWTP			
UT0020931	UT	16010204	CORINNE- CITY OF	Bear River	Bear River an undetermined distance below City of Corinne WWTP			
UT0021148	UT	16010204	PERRY CITY	Bear River	Perry City at Bear River Bay - GSL	253	1.35	lbs/day ammonia
UT0021920	UT	16010202	LOGAN CITY CORPORATION	Cutler Reservoir - Bear River	Logan City Corp at Cutler REservoir			
UT0022233	UT	16010203	MILLER BROS FEED YARD	Not available	MILLER BROS FEED YARD			
UT0022365	UT	16010204	BRIGHAM CITY CORP	Box Elder Creek	Discharge stream from Brigham Citiy Corp an undetermined distance down box Elder Creek			
UT0022608	UT	16010202	DAIRY CAPITAL CORP	Not available	DAIRY CAPITAL CORP			
UT0022632	UT	16010202	KUNZLER-DARRELL C	Not available	KUNZLER-DARRELL C			
UT0023205	UT	16010203	HYRUM CITY CORPORTATION	Ditch - Spring Creek	Discharge stream from Hyrum City Corp. WWTP an undetermined distance down the ditch to Spring Creek			
UT0023850	UT	16010204	NUCOR STEEL-DIV OF NUCOR CORP	Ditch - Malad River	Discharge stream from Nucor Steel and undetermined distnace down a gully to the Malad River			
UT0024309	UT	16010202	GOSSNER FOODS, INC	Blue Spring drainage - Cutler Reservoir - Be	Discharge stream from Gossner Foods Inc an undetermined distance down the Blue Spring Drainage			
UT0024872	UT	16010203	NORTHERN UTAH MFG.	Ditch - Little Bear River	Discharge stream from Magic Valley Milk an undetermined distance down Hansen Spring drainage.	13.6	2.7	lbs/day ammonia
UT0025186	UT	16010203	SILICONE PLASTICS	Ditch - Blacksmith Fork River	Discharge stream from Silicone Plastics and undetermined distance down the ditch to Blacksmith Fork River			
UTG130015	UT	16010203	Trout of Paradise	Little Bear River	Little Bear River an undetermined distance below Trout of Paradise			
WY0020095	WY	16010101	City Of Evanston	Yellow Creek	Yellow Creek an undetermined distance below Evanston WWT			
WY0021032	WY	16010101	Cokeville Wastwater Lagoons	Bear River	Bear River an undetermined distance below Cokeville WWTP			
WY0031712	WY	16010101	North Uinta Co. Improvement &	Bear River	Bear River an undetermined distance below North Unita county W&S District WWTP			
WY0032697	WY	16010101	Chevron Inc	North Fork of Sheep Creek	Carter Creek Gas Plant			

7. Conclusions

At the start of this project two objectives were set: 1) achieving a holistic dataset on water quality in the Bear River Basin and 2) determining point and non-point sources of nitrogen loading in the surface water.

The first part of this objective was fulfilled through displaying datasets on different topics: landcover, impaired rivers and streams, water quality measurements etc. Using GIS for displaying these datasets is useful for getting an overview of the whole basin. Patterns were shown, indicating a higher nitrogen concentration downstream of the Bear River.

The second objective is partially fulfilled; however certain improvements can be made. The point sources for pollution are indicated and the locations are shown on the maps. A distinction needs to be made to determine the point sources causing high nitrogen loading in the surface water. Additionally, information on the actually nitrogen load for each month in the year can be used to calculate the nitrogen loading in the surface water.

Nonpoint sources were assumed to be mainly agricultural runoff therefore the analysis was performed on the agricultural areas per subcatchment. These results gave interesting trends, which coincide with the water sample measurements by USGS stations. Higher nitrogen loadings were found downstream of the Bear River and in intensely cultivated areas.

GIS provided tools to easily calculate with raster datasets and therefore execute an equation for each grid cell. It can also be used for further modeling to get more accurate results for nitrogen loading. The current calculation does not take into account the influence of soil texture and fertilizer management. Additionally nitrogen in the surface water will be used by the bacteria, so there is some decrease in nitrogen concentration due to bacterial consumption. These factors can be part of a greater model programmed with a schematic network and python operations as introduced in exercise 5. The results from this project give several basic datasets and useful estimations on the patterns observed concerning nitrogen loading in the Bear River.