Summary of the Roads Network in the Flathead Lake Basin

March 1, 2010

Public Review Draft

U.S. Environmental Protection Agency
Montana Operations Office
10 West 15th Street, Suite 3200
Helena, MT 59601

Project Manager: Ron Steg

Revision History

Document Name	Revision	Release Date	Revisions
Flathead Basin TMDL Technical Report —Roads; Stakeholder Review Draft	1.0	June 16, 2009	Draft was sent to public entities that contributed data and information to the report.
Flathead Basin TMDL Technical Report — Roads; Public Review Draft	2.0	March 1, 2010	Received and incorporated comments from Plum Creek, Missoula County, Glacier National Park, Flathead County, and ITSD

Table of Contents

1.0 INTRODUCTION ... **1**
2.0 ROAD IMPACTS TO HYDROLOGY AND WATER QUALITY ... **1**
2.1 Water Infiltration and Yield ... 1
2.2 Sediment ... 2
2.3 Nutrients ... 2
2.4 Site-Specific Studies ... 2
3.0 AVAILABLE ROADS DATA ... **6**
3.1 TIGER ... 6
3.2 ITSD Transportation Framework ... 9
3.3 Flathead National Forest ... 11
3.4 Glacier National Park ... 13
3.5 Flathead County ... 15
3.6 Lake County ... 17
3.7 Missoula County ... 19
3.8 Montana Department of Natural Resources and Conservation ... 21
3.9 British Columbia National Road Network ... 23
3.10 British Columbia Forest Roads ... 25
3.11 CSKT ... 27
3.12 Plum Creek Timber Company ... 27
3.13 Roads Summary ... 27
4.0 COMPILATION OF ROADS DATA ... **34**
4.1 Preparing Data for Analysis ... 36
4.2 Data Analysis ... 38
4.3 Compilation of Final Dataset ... 41
4.4 Quality Control ... 42
5.0 ROADS SUMMARY ... **50**
6.0 DATA GAPS ... **50**
7.0 REFERENCES ... **51**

Tables

Table 1. Road / Stream Crossing Summary. ... 5
Table 2. Summary of annual road sediment loads from four watersheds in the Flathead Lake Basin. ... 5
Table 3. Summary of road types and miles in the TIGER 2007 GIS files. ... 7
Table 4. Summary of road surface and miles in the ITSD road coverage. ... 9
Table 5. Summary of road surface and miles in the FNF road coverage. ... 11
Table 6. Summary of road surface and miles in the GNP road coverage. ... 13
Table 7. Summary of road surface and miles in the Flathead County road coverage. ... 15
Table 8. Summary of road surface and miles in the Lake County road coverage. ... 17
Table 9. Summary of road surface and miles in the National Road Network coverage. ... 23
Table 10. Summary of road data for the Flathead Lake watershed. ... 28
Table 11. Accuracy analysis of the master roads file. ... 44
Table 12. Summary of road surface and miles for the master roads coverage. ... 50

Figures

Figure 1. 2007 TIGER file roads in the Flathead Lake watershed. 8
Figure 2. ITSD roads in the Flathead Lake watershed. 10
Figure 3. Flathead National Forest roads in the Flathead Lake watershed. 12
Figure 4. Glacier National Park roads in the Flathead Lake watershed. 14
Figure 5. Flathead County roads in the Flathead Lake watershed. 16
Figure 6. Lake County roads in the Flathead Lake watershed. 18
Figure 7. Missoula County roads in the Flathead Lake watershed. 20
Figure 8. Montana DNRC Roads in the Flathead Lake watershed. 22
Figure 9. British Columbia National Roads Network in the Flathead Lake watershed. 24
Figure 10. British Columbia Forest Roads in the Flathead Lake watershed. 26
Figure 11. Comparison of the ITSD and Flathead National Forest Roads (Goat Creek subbasin in the Swan River watershed). Note that both coverages contain roads not included in the other. 31
Figure 12. Comparison of the ITSD and Flathead National Forest Roads. Note that both coverages contain roads not included in the other. However, the ITSD coverage contains most of the FNF roads (left map above), although not as many attributes. 32
Figure 13. Comparison of the ITSD and Flathead County Roads (northwest corner of Kalispell). Note that the Flathead County Roads coverage is more up to date, showing new roads/subdivisions northwest of Kalispell. Also note that the Flathead County roads coverage shows alleys not included in the ITSD coverage. 33
Figure 14. Master roads coverage in the Flathead Lake watershed. 35
Figure 15. Flathead County quadrants. 37
Figure 16. Location of unique roads in the ITSD GIS coverage. 37
Figure 17. Example of original roads coverages 39
Figure 18. Example of unique segments from MatchStix output using 50 meter tolerance. Note how the smaller Missoula County segment does not intersect with the FNF segment 40
Figure 19. Example of unique segments from MatchStix output using 100 meter tolerance. Note how both Missoula County segments do not intersect the FNF segment. 41
Figure 20. Quality control for T23N R20W S30. 45
Figure 21. Quality control for T24N R21W S3. 46
Figure 22. Quality control for T25N R19W S10. 46
Figure 23. Quality control for T27N R21W S11. 46
Figure 24. Quality control for T28N R22W S12. 47
Figure 25. Quality control for T28N R24W S27. 47
Figure 26. Quality control for T29N R17W S8. 48
Figure 27. Quality control for t29N R24W S9. 48
Figure 28. Quality control for T31N R21W S11. 49
Figure 29. Quality control for T33N R19W S27. 49

Foreward

A series of brief technical reports have been prepared by the U.S. Environmental Protection Agency (EPA) in support of an effort by the Montana Department of Environmental Quality (DEQ) and EPA to establish Total Maximum Daily Loads (TMDLs) for nutrients and set up a water quality simulation model for the Flathead Basin. The series includes separate reports covering a broad range of topics including:

- Groundwater Quality and Hydrology
- Urban Stormwater Sources
- Point Source Discharges
- Agriculture/Irrigation
- Timber Harvest
- Forest Fires
- Roads
- Septic Systems
- Lakes and Reservoirs
- Existing and historic water quality in nutrient impaired waters

When combined, these technical reports are intended to define a preliminary conceptual understanding of the current water quality conditions relative to nutrients, sources of nutrients, and the ways in which water and nutrients are transported within the Basin. The information presented in this series of technical reports will be used to inform the modeling and TMDL processes. However, specific details on model setup are not discussed in the technical reports – that information will be included in the forthcoming Modeling Quality Assurance Project Plan (QAPP).

It should be noted that the data and information presented in these reports reflects what was available at the time that the reports were published. It is acknowledged that in some cases, not all data could be compiled by the publication date. Additional information will be incorporated into the modeling and TMDL processes as it becomes available.

Executive Summary

All available GIS road coverages for the Flathead Basin were compiled and evaluated for their suitability in providing an accurate description of the road network. GIS roads data were compiled from: U.S. Census Bureau TIGER; ITSD Transportation Framework; Flathead National Forest; Glacier National Park; Flathead, Lake, and Missoula Counties; DNRC; and two data sets from British Columbia, Canada. Separately, none of the roads datasets provided a complete coverage of the basin. As a result, a "Master Roads Coverage" has been prepared including 10,202 miles of roads with 6,126 miles of roads having surface pavement attribute data. This is 13 percent more roads than the next highest density roads coverage (ITSD – 9,019 miles) and includes more accurate and updated data reflecting 2007 and some 2008 road additions in some areas. In lieu of a complex aerial photo interpretation and digitization effort, the generated master coverage is believed to be the most comprehensive coverage available for the Flathead Lake watershed.

1.0 Introduction

This is one of a series of brief technical reports prepared in support of an effort by the Montana Department of Environmental Quality (DEQ) and U.S. Environmental Protection Agency (EPA) to establish Total Maximum Daily Loads (TMDLs) for nutrients, sediment, and temperature and set up a water quality simulation model for the Flathead Basin. Roads are one of many potentially significant sources of pollutants within the Basin that will ultimately be considered in the modeling effort. The purpose of this technical report is to provide a summary of the extent and type of roads that are located within the Flathead Basin. The results will then be used to inform the modeling and TMDL processes.

It should be noted that this memo is intended to simply characterize the existing roads network. The memo does not provide details on the methodology for modeling roads and/or pollutant loads from roads – that information will be included in the forthcoming Modeling Quality Assurance Project Plan (QAPP).

2.0 Road Impacts to Hydrology and Water Quality

The following sections provide a brief summary of the potential effects of roads on water quality and watershed hydrologic response, and summarize the site-specific studies that have been completed to date in the Flathead Basin. This is not intended to be a comprehensive review of the literature. Rather, the following sections are intended to provide basic background information on the impacts of roads to water flow and chemistry.

2.1 Water Infiltration and Yield

Roads and their impacts to water yield are generally discussed in the literature in two different contexts – paved roads associated with impervious surfaces in an urban setting, and unpaved roads associated with forestry and logging practices. Regardless, both types of roads impact water infiltration and yield in the same manner. Roads reduce (or eliminate) infiltration, and can increase peak storm flows and reduce base flows in streams (CWP, 2003; Anderson et al., 1976).

2.2 Sediment

Forest roads increase sediment erosion and delivery through direct erosion of the road prism, cutslopes, and mass wasting. Erosion rates vary depending on the type of soil, slope, road material, road design, traffic level, and amount of precipitation (Elliot et al., 2000). Sediment delivery to a stream then depends on the road slope, horizontal length, conveyance methods, and any BMPs/treatments located between the road and stream (Anderson et al., 1976). As one example of the potential magnitude of sediment loading from forest roads, Sugden and Woods (2007) found that the annual sediment yields from unpaved forest roads ranged from 0 to 96.9 Mg/ha/yr over 3 years (2002-2004), and annual mean sediment yields ranged from 2.1 Mg/ha in 2003 to 9.9 Mg/ha in 2004 with an overall mean of 5.4 Mg/ha/year. It should be noted that sediment yield from unpaved roads varies considerably based on the characteristics of the road network, design and condition of the roads, and environmental characteristics of the surrounding area.

Road-stream crossings are another source of sediment to streams. Studies have found the culverts, fords, and bridges increase sediment loading to streams, particularly during installation and/or failure (as summarized in Taylor et al., 1999).

2.3 Nutrients

Forest roads are likely to be the dominant source of human-induced sediment and nutrients delivered to streams from managed forests (Sheridan and Noske, 2008). Nutrient movement to streams often increases significantly after timber harvest operations and the increased nutrient supply to streams from roads is proportional to the area disturbed and maintained free of vegetation and the amount of sediment delivered (Gucinski et. al.,2001).

2.4 Site-Specific Studies

A number of site specific studies, evaluating the potential water quality impacts of roads, have been conducted within the Flathead Basin. Additionally, in response to some of these site-specific studies, road restoration work has been conducted to minimize and/or eliminate the potential water quality impacts. These are presented herein to point out for the reader that detailed data and information regarding the potential impacts of roads within the Flathead Basin is available for some limited areas.

Swan Lake TMDL

As part of the Swan Lake TMDL process (DEQ, 2004) 1,110 stream crossings were identified in the Swan Lake Watershed. Of those, 702 were visited on the ground 318 were found to be contributing sediment to streams, 228 were determined to be non-contributing due to extensive revegetation, and 156 were stream crossings that appeared on GIS mapping layers but did not actually exist on the ground. The 318 contributing sites were estimated to have a combined sediment load of 799 tons/year.

Of the 318 contributing sites visited on the ground, 25 were on non-industrial private land. These 25 private crossings had an average sediment contribution of 2.1 tons/year, and this average was applied to the 110 private crossings that were not visited on the ground, resulting in a total estimated sediment load from non-inventoried private crossings of 231 tons/year. Note that in this analysis, “private” refers to private land other than that owned by Plum Creek Timber Company, who provided unlimited access to the company’s land.

Of the 318 contributing sites, 260 were low potential sites with an average estimated sediment load of 0.19 tons/year each. This average was applied to each of the remaining 298 sites that were not visited, all of which were low potential sites, resulting in a total estimated sediment load from non-inventoried low potential sites of 57 tons/year. Thus the total estimated sediment load from all road crossings in the Swan Lake Watershed was 1087 tons/year (799 + 231 + 57).

To date, the Flathead National Forest has addressed 80 sites resulting in an estimated 230 ton reduction in sediment loading in the Swan River Watershed (personal communication, Liz Hill, December 15, 2008).

Goat and Piper Creek Study

Another assessment of sediment loading to streams from forest roads was done in 1996 under the direction of Plum Creek Timber Company (Watson et al, 1998) as part of a watershed analysis for Goat Creek and Piper Creek within the Swan Lake Watershed. In the Goat Creek watershed (including Squeezer Creek drainage), estimated sediment production from roads was 39.3 tons/year, of which 72% was from road tread and 28% from cut slopes and fill slopes. The road erosion in the Goat Creek watershed (above Squeezer Creek) was estimated at 11% above natural background, and estimated at only 0.2% above background in the Squeezer Creek drainage since the assessment of sediment loading from this portion of the Goat Creek watershed was less than 1 ton/year.

In the Piper Creek watershed, the 1996 estimate of sediment production from roads was 25.5 tons/year, which was estimated to be 24% above natural background. The majority of the sediment loading came from a minority of stream crossings in both the Goat and Piper watersheds, with the worst five crossings contributing 70% of the total sediment load in the Goat Creek watershed.

In 1997, recognizing the impacts that forestry practices may have on bull trout, Plum Creek Timber Company met with the US Fish and Wildlife Service to initiate the development of the Native Fish Habitat Conservation Plan (NFHCP). Under this plan, all old roads for which Plum Creek Timber Company has direct or shared responsibility must be upgraded to an improved erosion control standard by the end of 2015.

The Plum Creek Timber Company has installed BMPs on existing roads within the Goat and Piper Creek watersheds. The most common BMPs installed are relief culverts and driveable drain dips that redirect sediment during snowmelt or rain events from the road to infiltration areas on adjacent slopes, preventing sediment from entering the stream channels. Plum Creek also designs and constructs new roads with enhanced BMPs that exceed existing state rules and current BMP standards.

The US Forest Service has also implemented BMPs to reduce sediment input into the stream from roads. For example, along Piper Creek they have installed a series of sediment control techniques at a primary stream crossing where there was significant sediment runoff directly into the stream.

The cumulative effects of these on-the-ground efforts, combined with improved silviculture techniques and other land management enhancements has led to decreased concentrations of suspended solids and nutrients in Goat and Piper Creeks. Water quality assessment efforts conducted to support the Water Quality Plan/TMDL in 2004 have indicated that Goat and Piper Creeks are meeting water quality standards for these pollutants (except for suspended solids in Upper Goat Creek). Both suspended solids and nutrients are within the range of nature background levels. Plum Creek Timber Co. also performed water quality assessments and estimated that restoration efforts have led to a 29% and 71% decrease in sediment delivered to Goat and Piper Creeks, respectively. The improvements to water quality are attributed to installation of road BMPs, recovery from past timber harvest practices, application of timber harvest BMPs for water quality protection, and protection of riparian zones.

Swan View Coalition Study

The Bitterroot, Flathead and Lolo National Forests conducted baseline bull trout risk assessments finding the majority of the sub-watersheds assessed are at risk from the effects of existing roads (Hammer, 2004). The results relative to the Flathead National Forest are provided below:

> *The Flathead National Forest provided baseline bull trout risk assessments (Gardner 2000a, 2000b and VanEimeren 2000a, 2000b) for 79 of the 169 sub-watersheds within the Flathead National Forest boundary. The remaining sub-watersheds were not assessed by the Flathead because they are either in congressionally designated wilderness areas, are not known to be used by bull trout, or are located essentially on lands not administered by the US Forest Service. The Flathead's assessments found that, due to existing road densities and road locations, only 30% of the assessed sub-watersheds were Functioning Appropriately, while 32% were found to be Functioning at Risk and 38% were found to be Functioning at Unacceptable Risk.*

Flathead Headwaters TMDL

Under an interagency agreement with the EPA, the Flathead National Forest conducted a sediment source assessment survey in support of the development of all necessary TMDLs for the Flathead Headwaters TMDL Planning Area (TPA). The Flathead Headwaters TPA encompasses the watersheds of the North, Middle, and South Forks of the Flathead River. Potential sediment contributions from roads were evaluated for the drainages of Red Meadow, Whale, Coal, Granite, Skyland, Morrison, and Sullivan Creeks. In 2002 and 2003, the FNF field crew completed driving and walking surveys on all open, closed, decommissioned, and maintained roads (except in Sullivan Creek) to identify active road sediment sources. Table 1 provides summary information on stream crossings and roads located in each watershed.

Table 1. Road / Stream Crossing Summary.

Stream Segment	Number of Road/Stream Crossings	Number of Road/Stream Crossings Evaluated	Number of Road/Stream Crossings at Failure Risk in the Watershed	Road miles in need of BMP's or upgrading	Road miles within 125' of stream	Road miles within 300' of stream
Red Meadow Creek	76	76	0	9	14.6	16.9
Whale Creek	84	84	8	21	26.8	30.2
FNF Coal Creek	142	135	16	40	13.8	34.9
Granite Creek	16	16	2	18	1.7	5.5
Skyland Creek	13	13	0	0	2.3	2.5
Morrison Creek	5	5	0	0	6.9	1.7
Sullivan Creek	103	55	Partially completed 2003 with BAER Fire funds	Partially completed 2003 with BAER Fire funds	7.1	25.7

Plum Creek Studies

Plum Creek has estimated sediment contribution to streams from company roads in four watersheds in the Flathead River Basin (exclusive of the Swan River sub-basin). These watersheds include Lazy Creek (tributary to Whitefish Lake), Freeland Creek (tributary to Lake Mary Ronan), Fish Creek (tributary to Ashley Lake), and Upper Dayton Creek (tributary to Flathead Lake) (Sudgen, 2010). Plum Creek inventoried approximately 75 percent of the road-stream interactions in the four watersheds. Using a modified version of the Standard Methodology for Watershed Analysis (Washington Forest Practices Board 1997), sediment loads were estimated for each watershed and are summarized in Table 2. The median and average estimated sediment loads per site were 0.05 and 0.08 tons/year, respectively, and sediment loads ranged from 0 to 0.81 tons/year/site.

Table 2. Summary of annual road sediment loads from four watersheds in the Flathead Lake Basin.

Watershed/ Percent Inventoried	Estimated Average Annual Road Sediment Contribution (tons/yr)	Extrapolated Average Annual Road Sediment Contribution (tons/yr)	Extrapolated Road Sediment Delivery per Unit Area (tons/mi^2)
Dayton (60%)	1.4	2.3	0.12
Fish (100%)	0.8	0.8	0.29
Freeland (100%)	4.6	4.6	0.37
Lazy (75%)	1.1	1.5	0.09
Total Estimated	7.9	9.2	0.18

3.0 Available Roads Data

Several agencies in Montana and British Columbia maintain GIS road coverages. Data were obtained from the various agencies and the following sections summarize each of the known GIS coverages.

3.1 TIGER

The U.S. Census Bureau maintains the Census Master Address File/Topologically Integrated Geographic Encoding and Referencing database (MAF/TIGER) (U.S. Census Bureau, 2007). The Census Bureau releases to the public extracts of the database in the form of TIGER/Line shapefiles, including road networks. The road networks were developed from USGS's 1:100,000 scale topographic maps, which were scanned in and converted to a GIS coverage (U.S. Census Bureau, 2006).

The 2007 TIGER shapefiles were downloaded from http://www.census.gov/geo/www/tiger/ on April 17, 2008. Data were obtained for Flathead, Lake, Lewis and Clark, Lincoln, Missoula, and Powell counties, which were then combined and clipped into one shapefile of all roads in the Flathead Lake watershed. The TIGER files for the Flathead Lake watershed contain the following road attributes relative to road use:

- Alley
- Local Neighborhood Road, Rural Road, City Street
- Private Road for service vehicles (logging, oil fields, ranches, etc.)
- Secondary Road
- Service Drive usually along a limited access highway
- Vehicular Trail (4WD)

No information was provided regarding road surfaces (e.g., paved, gravel, natural) or width. However, road surfaces can be inferred from some of the descriptions (e.g., vehicular trail-4WD is an unpaved road). Table 3 provides a summary of the TIGER road types and total number of road miles in the Flathead Lake watershed. Figure 1 shows the 2007 TIGER roads for the Flathead Lake watershed.

Table 3. Summary of road types and miles in the TIGER 2007 GIS files.

Description	**Road Length (miles)**
Local Neighborhood Road, Rural Road, City Street	6,478
Private Road for service vehicles (logging, oil fields, ranches, etc.)	386
Secondary Road	362
Vehicular Trail (4WD)	152
Alley	4
Service Drive usually along a limited access highway	1
Total	**7,383**

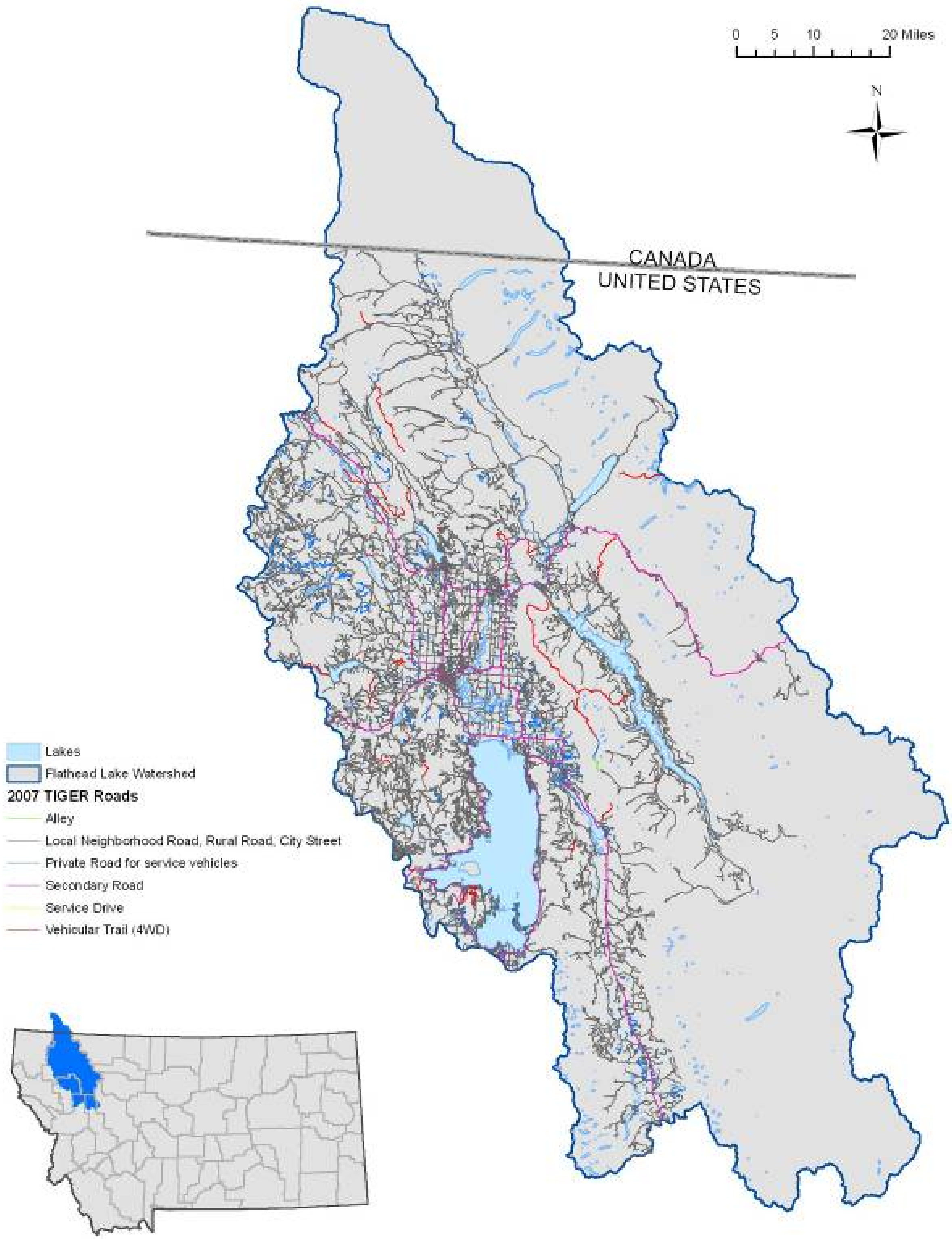

Figure 1. 2007 TIGER file roads in the Flathead Lake watershed.

3.2 ITSD Transportation Framework

The Montana Department of Administration's Information Technology Services Division (ITSD) maintains a database and GIS layers of roads in Montana. The metadata states that:

> *"the information depicted in this GIS layer is the result of digital analyses performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the data," (ITSD, 2007).*

The geodatabase coverage for the entire state of Montana (titled "Roads from the Montana Transportation Framework Layer") was downloaded from ftp://ftp.gis.mt.gov/TransportationFramework on March 14, 2008. The publication date of the database is February 15, 2007 and is edition 1.7. However, the publication date for the Flathead County roads (included within the ITSD coverage) is June 4, 2003 (Personal Communications, Joshua Dorris, ITSD, May 15, 2008). No information was available for the other counties or data sources.

The geodatabase (TransFramework_9_2_Personal.mdb) covers the entire state of Montana. It was imported into ArcGIS and clipped to the Flathead Lake Watershed using a USGS 8-Digit HUC layer. The GIS coverage contains the following road surface attributes: crushed aggregate or gravel, gravel, native material, and paved. No information was available regarding road use or width.

Table 4 provides a summary of the ITSD road surfaces and total number of road miles in the Flathead Lake watershed. It should be noted that only 4,756 miles of roads out of 9,019 miles (53 percent) had road surface attributes. Figure 1 shows the ITSD roads for the Flathead Lake watershed.

Table 4. Summary of road surface and miles in the ITSD road coverage.

Description	Road Length (miles)
Unknown	4,756
Native material	3,534
Crushed aggregate or gravel	406
Gravel	197
Paved	126
Total	**9,019**

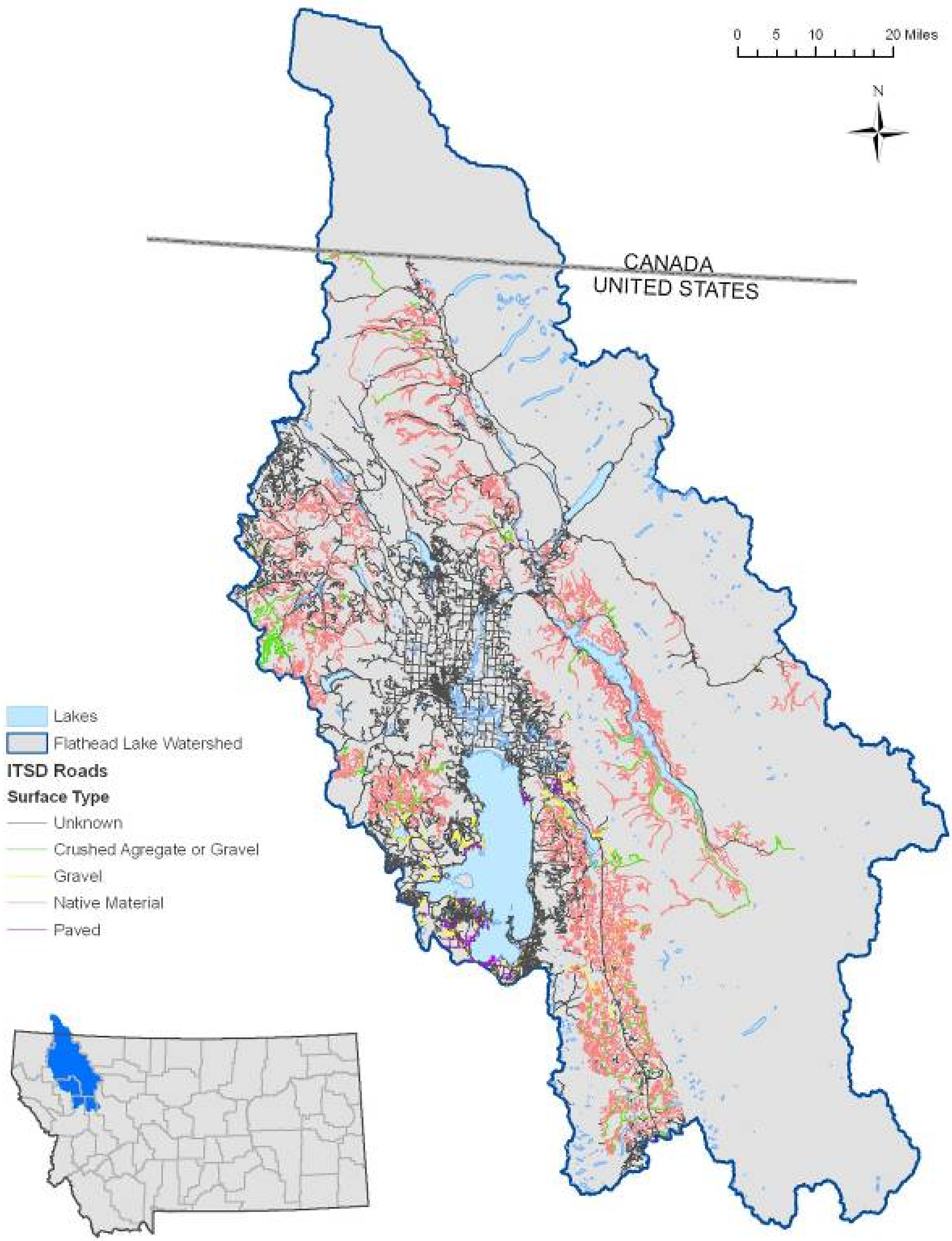

Figure 2. ITSD roads in the Flathead Lake watershed.

3.3 Flathead National Forest

The Flathead National Forest (FNF) was contacted to obtain road information within the Forest Service boundary of the Flathead Lake watershed. Dennis McCarthy (Geospatial Program Manager for the Flathead National Forest) provided a GIS shapefile of Forest Service roads on April 4, 2008. The file contained information for both National Forest roads and other roads in or near the Flathead National Forest.

The source of the roads data is the 1985 Forest Service Cartographic Feature Files (CFF), which is a "*digital data file containing a vector representation of the point and line features shown on a Forest Service Primary Base Series (PBS) map*," (USFS, 2002). The Primary Base Series maps were constructed from U.S. Geological Survey (USGS) 7.5 minute topographic quadrangle maps (1:24,000 scale), and then were revised using correction guide information provided by field units. Metadata states that the roads coverage was last updated on January 27, 2005 (USFS, 2002).

The shapefile contained the following road attributes that are of interest for this assessment:

- **Travel Management –** Open, no legal restrictions; Highway traffic; All motorized traffic; Impassible prism exists; Some motorized traffic.
- **Objective –** Basic custodial care (closed); High clearance vehicles; Suitable for passenger cars; Moderate degree of user comfort; High degree of user comfort; Convert use; Decommission.
- **Route Status –** Decommissioned; Existing; Planned
- **Surface Type –** Asphalt; Bituminous surface treatment; Crushed aggregate or gravel; Native material; Paved.

Table 5 provides a summary of the Flathead National Forest road surface types and total number of road miles in the Flathead Lake watershed. Figure 3 shows the FNF roads and the surface type for the Flathead Lake watershed.

Table 5. Summary of road surface and miles in the FNF road coverage.

Description	Road Length (miles)
Native Material	3,474
Crushed Aggregate or Gravel	1,004
Unknown	962
Paved	519
Bituminous Surface Treatment	2
Asphalt	1
Total	**5,962**

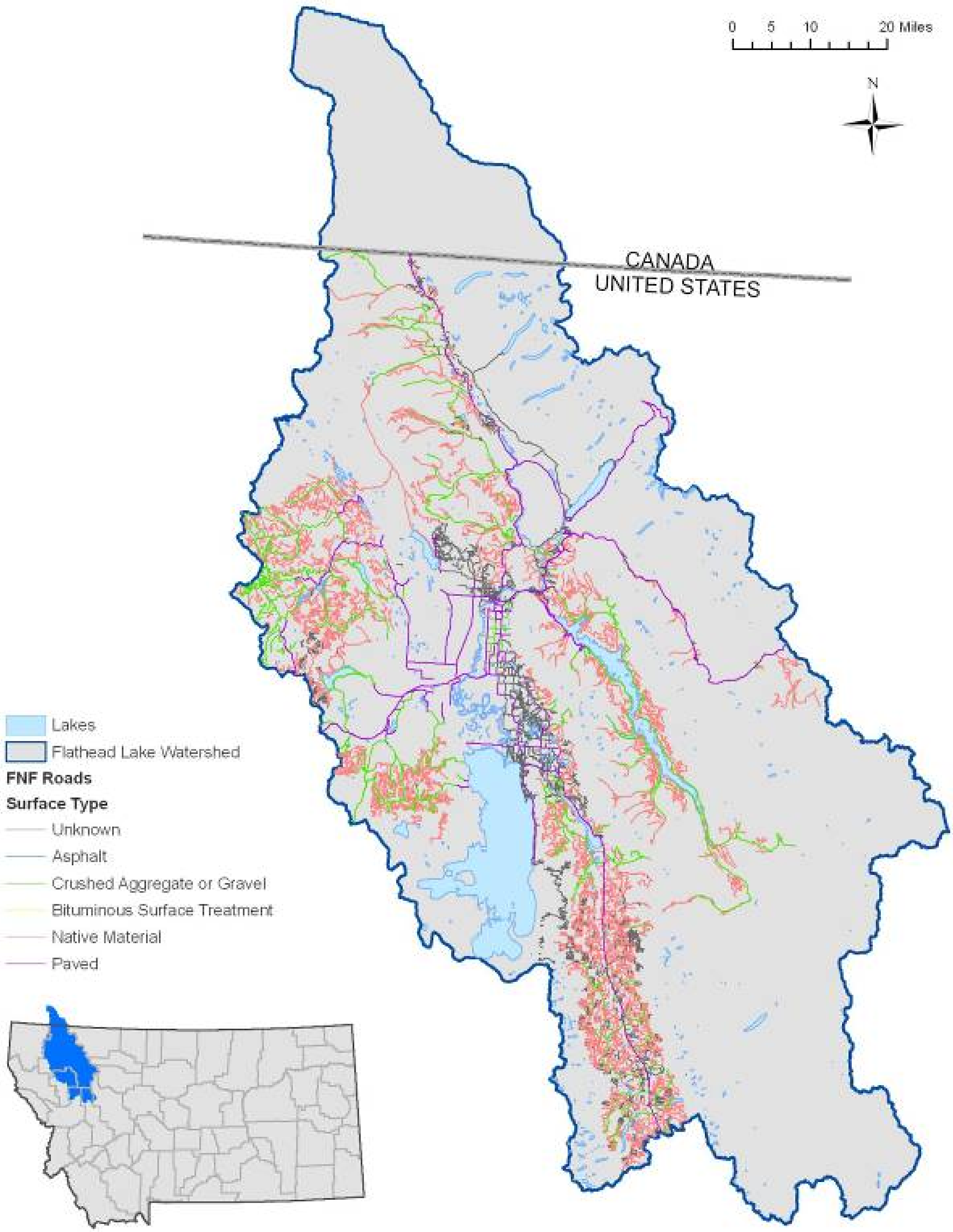

Figure 3. Flathead National Forest roads in the Flathead Lake watershed.

3.4 Glacier National Park

Glacier National Park (GNP) was contacted to obtain road information within the park boundary of the Flathead Lake watershed. Richard Menicke (Geographer/GIS Coordinator for Glacier National Park) provided a GIS shapefile with roads and attributes on March 24, 2008. Metadata for the shapefile states that, "*the data set attempts to map road centerlines where possible. This data set represents a significant edit to the park roads data, using 0.33-meter and 1-meter ortho-imagery to improve quality where possible,*" (GNP, 2008). The publication date of the shapefile is January 1, 2008.

The following attributes were present in the shapefile:

- **Class –** Administrative; Public primary; Public secondary; Private secondary.
- **Type (Surface Type) –** Paved; Unpaved.

Table 6 provides a summary of the Glacier National Park road types and total number of road miles in the Flathead Lake watershed. Figure 4 shows the GNP roads and the surface type in the Flathead Lake watershed.

Table 6. Summary of road surface and miles in the GNP road coverage.

Description	Road Length (miles)
Paved	134
Unpaved	106
Total	240

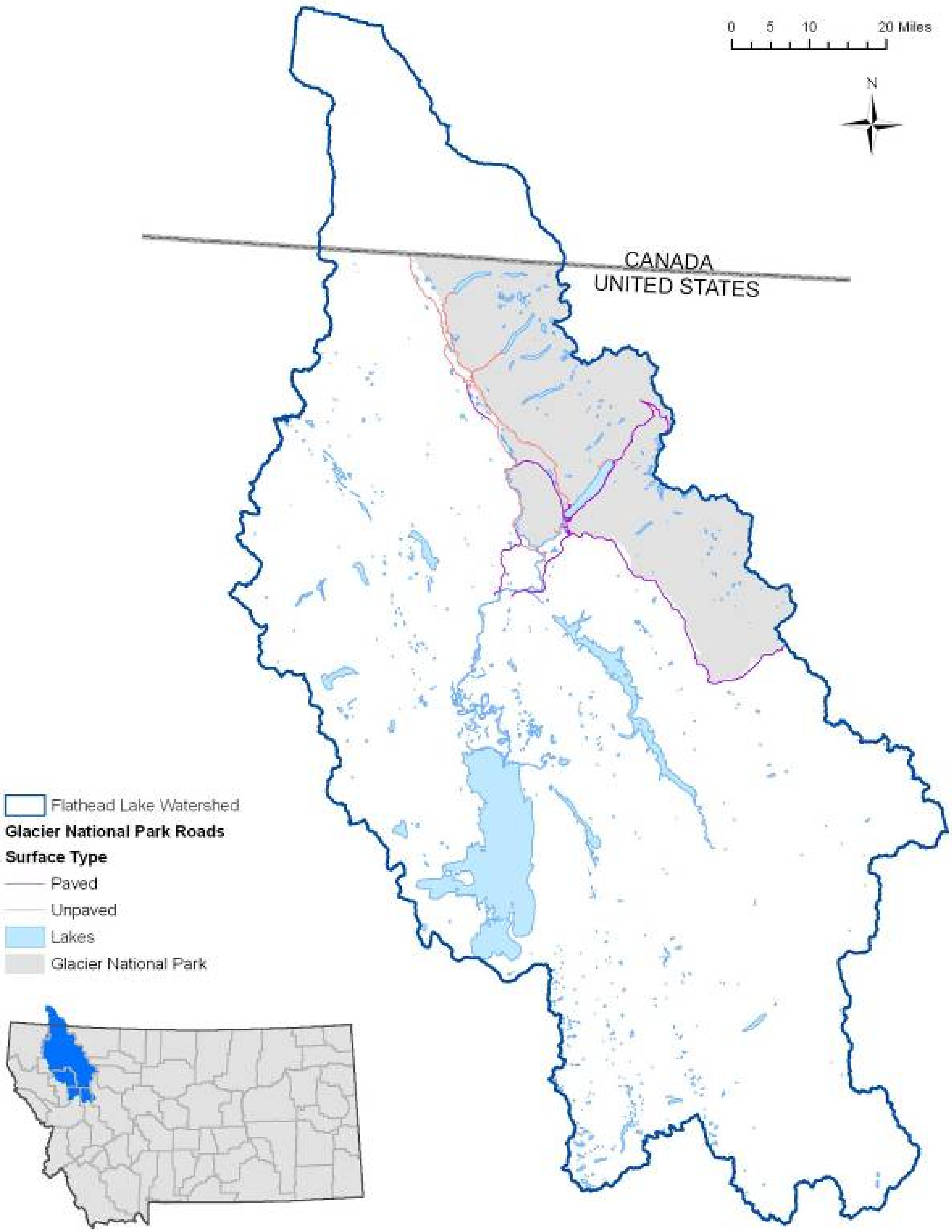

Figure 4. Glacier National Park roads in the Flathead Lake watershed.

3.5 Flathead County

Flathead County maintains a GIS layer of county roads. The metadata states that (Flathead County, 2006):

> *The data is exclusively comprised of differentially corrected GPS positions for roads and driveways within Flathead County. GPS data is logged by various Trimble GPS units, including Trimble TDC1, Trimble TSC1, and Trimble GeoXT. GPS positions are logged in 1 second intervals with settings of PDOP of 6, SNR 4, and elevation mask 15. The GPS data is differentially corrected using Flathead County's base station data files. Manual editing is performed on GPS data, which includes removing spikes and extending and trimming line segments to intersect adjoining roads. GPS data collection for this data set began in 1997 and will continue as roads continue to be built.*
>
> *Attributes have been taken from a variety of sources including the Flathead County road books and/or files. Blank enteries are common within city limits where Flathead County does not maintain road records. The "Type" field most often reflects the condition of the road when it was GPS'd and has no regular update schedule. Road names are derived from legal documents housed in the Flathead County Plat Room. Address ranges are assigned based on the location of neighboring addresses and should reflect theoretical locations for geocoding to approximately 1/4 mile accuracy. As time progresses, this accuracy is hoped to be improved."*

The GIS shapefile coverage for the entire county was downloaded from http://maps.co.flathead.mt.us/ on March 26, 2008. The publication date of the shapefile is current as of the download (the metadata states the file is continuously updated). The shapefile contained information on road surfaces (gravel, natural, or paved) and road widths. Table 7 provides a summary of the Flathead County road types and total number of road miles in the Flathead Lake watershed, and Figure 5 shows the roads and surface type in the Flathead Lake watershed.

Table 7. Summary of road surface and miles in the Flathead County road coverage.

Description	Road Length (miles)
Gravel	1,912
Paved	1,162
Natural	425
Unknown	64
Other	7
Total	**3,570**

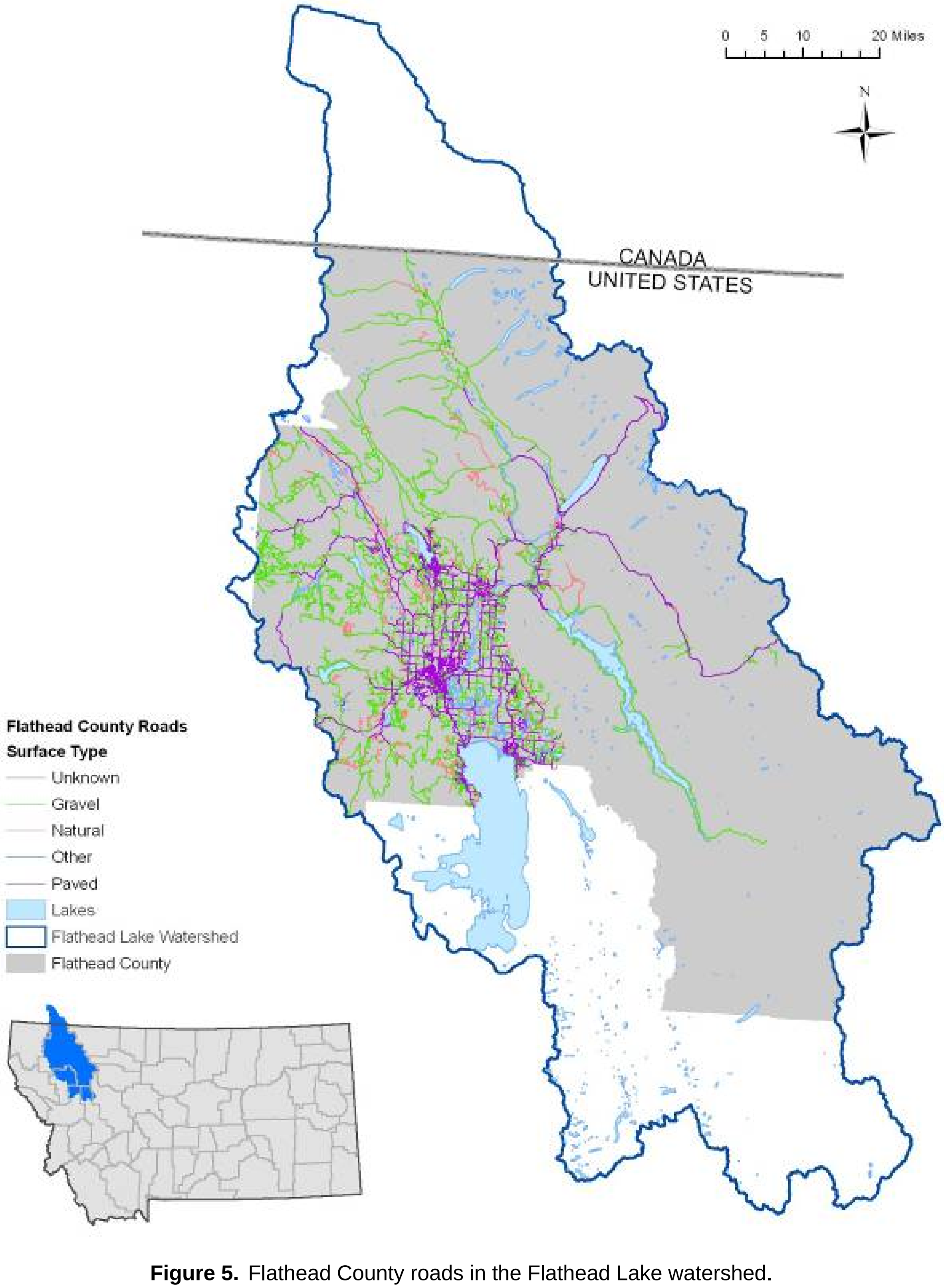

Figure 5. Flathead County roads in the Flathead Lake watershed.

3.6 Lake County

Lake County maintains a GIS layer of county roads. The metadata states that the, "*street centerline file was created using GPS equipment" and "is to be used for an accurate street centerline file to be used in conjunction with the creation of an enhanced 9-1-1 system, and address creation.*" (Lake County, 2007).

The GIS shapefile coverage for the entire county was downloaded from ftp://lakecounty-mt.org/ on April 22, 2008. The publication date of the shapefile is January 15, 2007. The shapefile contained information on road surfaces (gravel, dirt, and paved) and road type (alley, city street, forest rural road, local highway, private road, rural road, state highway, tribal road, and U.S. highway). Table 8 provides a summary of the Lake County road surfaces and total number of road miles in the Flathead Lake watershed. Figure 6 shows the roads and surface type in the Flathead Lake watershed.

Table 8. Summary of road surface and miles in the Lake County road coverage.

Description	Road Length (miles)
Unknown	384
Gravel	351
Dirt	305
Paved	249
Total	**1,289**

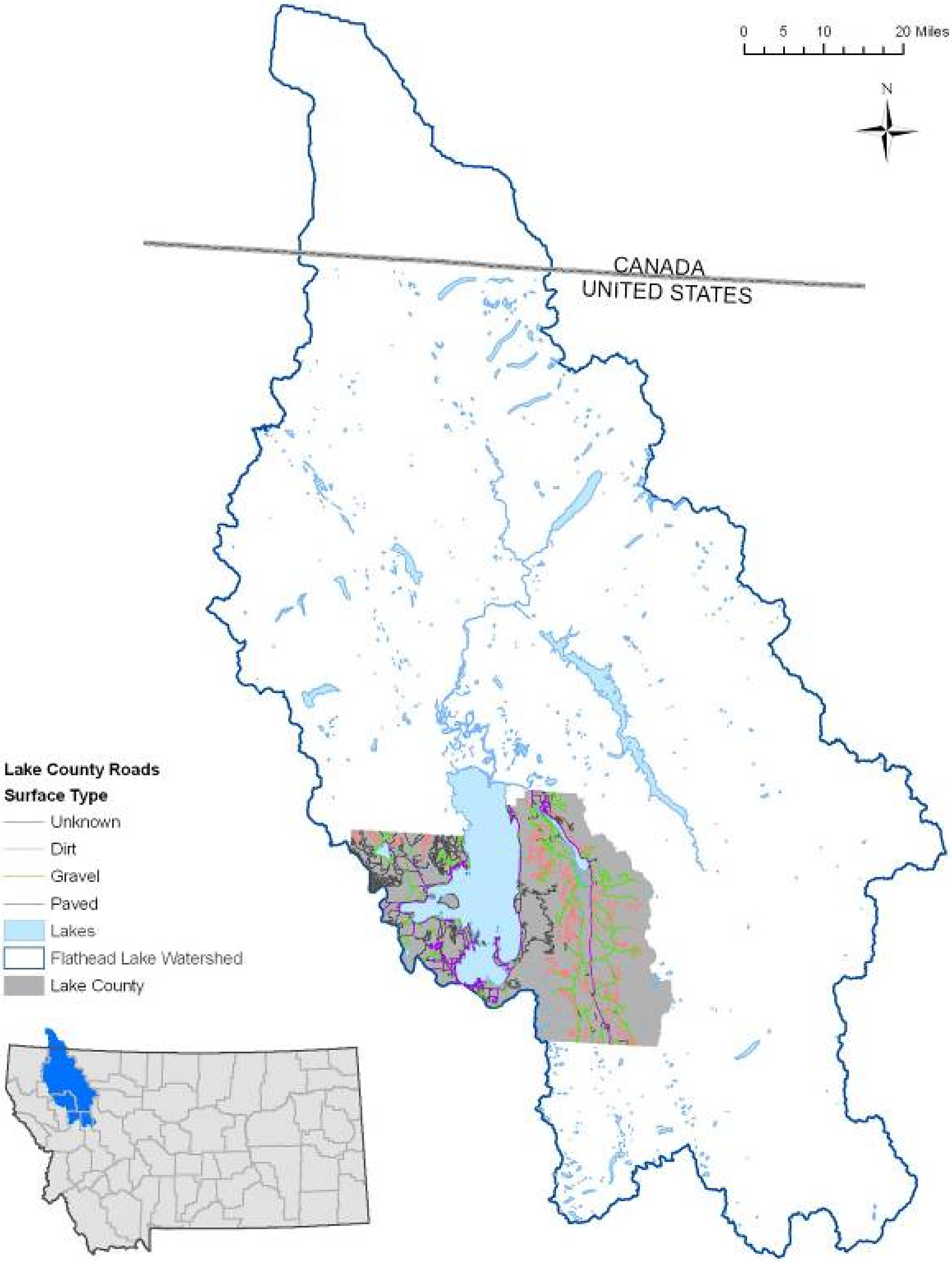

Figure 6. Lake County roads in the Flathead Lake watershed.

3.7 Missoula County

Missoula County maintains a GIS layer of county roads. The metadata file states (Missoula County, 2008),

> *This data set consists of a road centerline file of Highways, County Roads, City Streets and unnamed roads in Missoula County and also within those portions of Lake, Powell, Granite, Mineral and Ravalli Counities lying within the Missoula County 911 response jurisdiction. The original road centerlines for the above mentioned roads & highways were acquired from the 911 transportation database running in the Missoula County 911 Center in 11/30/01. The road centerline data was corrected from 1:100,000 scale accuracy to 1:24,000 scale accuracy by aligning road segments to existing ortho-imagery, road centerlines that were gps'ed in 2002 and lastly the Missoula County digital basemap data housed in the Missoula County Mapping GIS Department.*

The GIS shapefile coverage for the entire county was downloaded from http://www.co.missoula.mt.us/mapping_GIS/index.asp on April 22, 2008. The publication date of the shapefile is March 7, 2008. No information was available in the dataset regarding road use or surface type. A total of 578 miles of roads are included in the Flathead Lake watershed (Figure 7).

It should be noted that this GIS layer was primarily constructed to support 911 purposes (i.e., managing addressed locations for 911 purposes). Completeness of road data in national forest and private forest areas where residences do not exist is not of prime focus. Therefore, the coverage most likely does not have all forest roads mapped. Missoula County does try to incorporate forest roads from Plum Creek Timberlands into their GIS coverage, but this information is not up to date or complete (Personal Communications, Douglas Burreson, Mapping/GIS Supervisor, Missoula County, December 19, 2008).

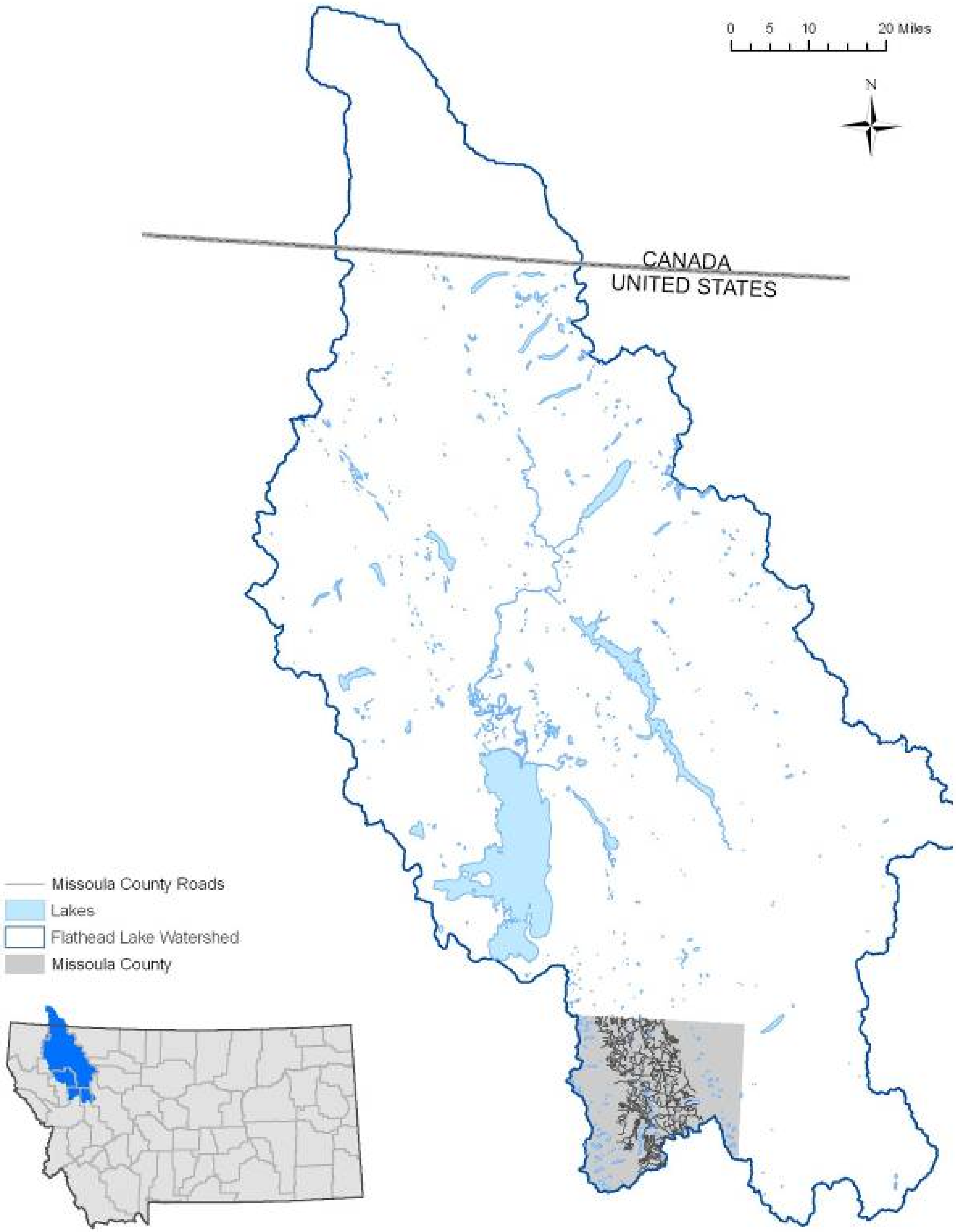

Figure 7. Missoula County roads in the Flathead Lake watershed.

3.8 Montana Department of Natural Resources and Conservation

Montana Department of Natural Resources and Conservation was contacted to obtain road information within DNRC-managed lands in the Flathead Lake watershed. Donna Riebe (GIS Analyst for DNRC) provided a GIS shapefile with roads and attributes on April 8, 2008. The layer contained 1,107 miles of roads in the Flathead Lake watershed (Figure 8). The only attributes for this shapefile were road class (i.e., easement, highway, impassible, open to public, private or administrative, proposed, public closure – seasonal, and public closure – YR). No information was available regarding road surfaces, width, or use.

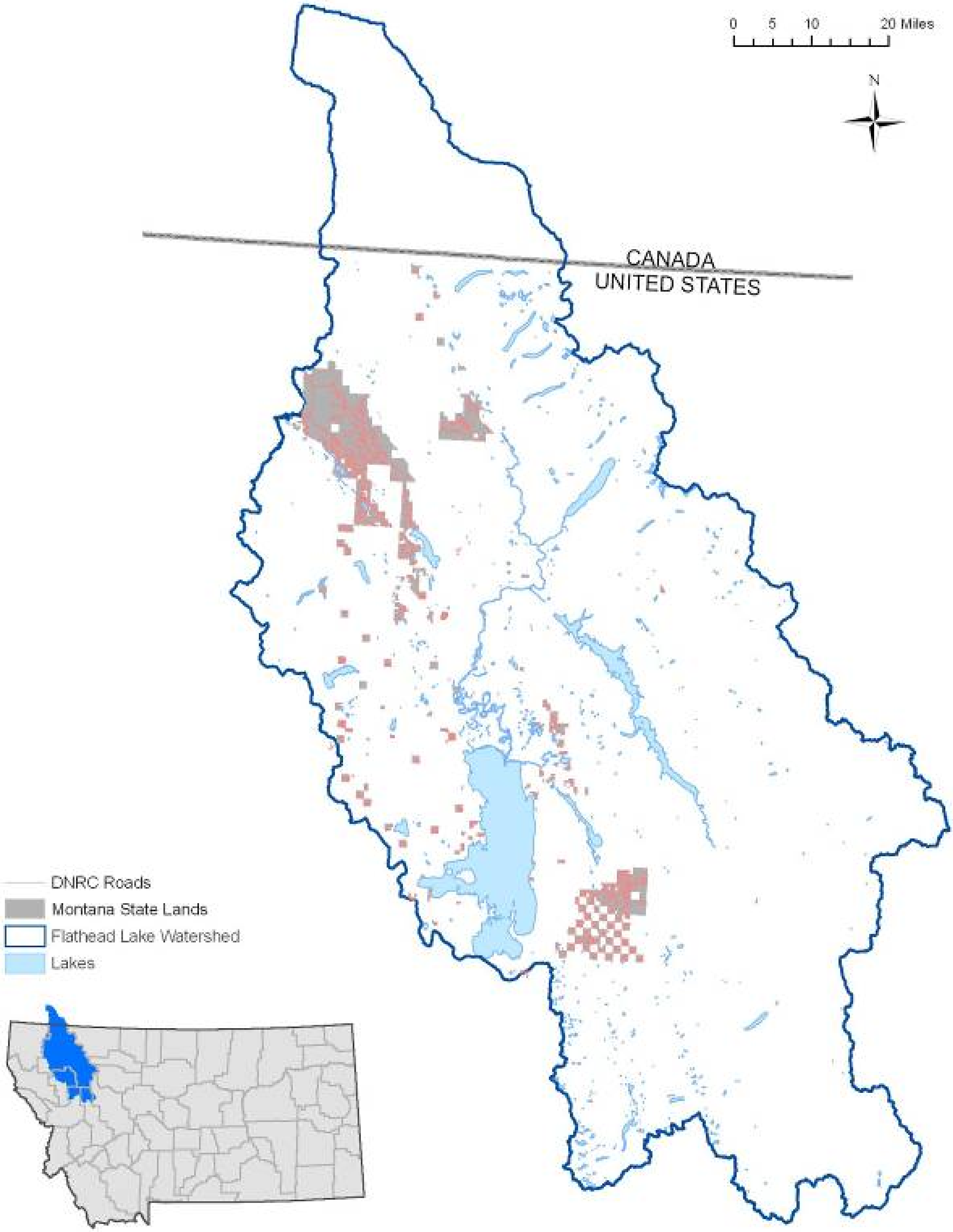

Figure 8. Montana DNRC Roads in the Flathead Lake watershed.

3.9 British Columbia National Road Network

The National Road Network for British Columbia was downloaded as a shapefile from http://www.geobase.ca/geobase/en/data/nrn/index.html on March 24, 2008. It was clipped to the Flathead Lake watershed in ArcMap 9.2. The publication data of the data is July 11, 2007. The following attribute fields are in the shapefile (as applicable to this report):

- Pavement Status – Paved; Unpaved.
- Road Class – Local/unknown; Resource/Recreation.

Table 9 provides a summary of the B.C. National Road Network surface type and total number of road miles in the Flathead Lake watershed. Figure 9 shows the roads in the Flathead Lake watershed.

Table 9. Summary of road surface and miles in the National Road Network coverage.

Description	Road Length (miles)
Paved	<1
Unpaved	112
Total	112

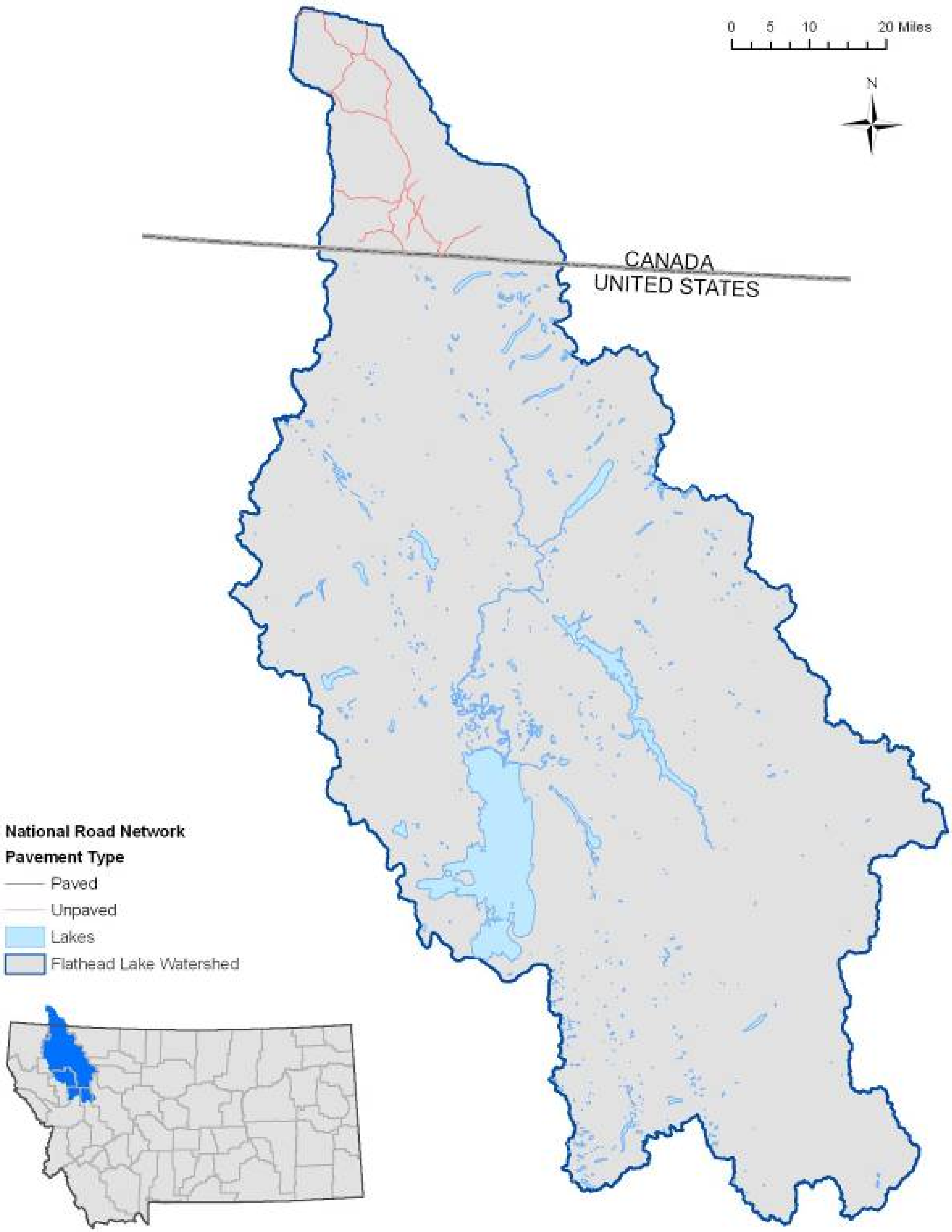

Figure 9. British Columbia National Roads Network in the Flathead Lake watershed.

3.10 British Columbia Forest Roads

The Integrated Land Management Bureau of British Columbia manages the Land and Resource Data Warehouse (LRDW), a repository for integrated land, resource and geographic data. A GIS layer of forest roads was downloaded from the website (http://www.lrdw.ca/) on April 25, 2008. The layer contained 236 miles of forest roads in the Flathead Lake watershed in B.C. (Figure 10). No information was available regarding road surfaces, width, or use.

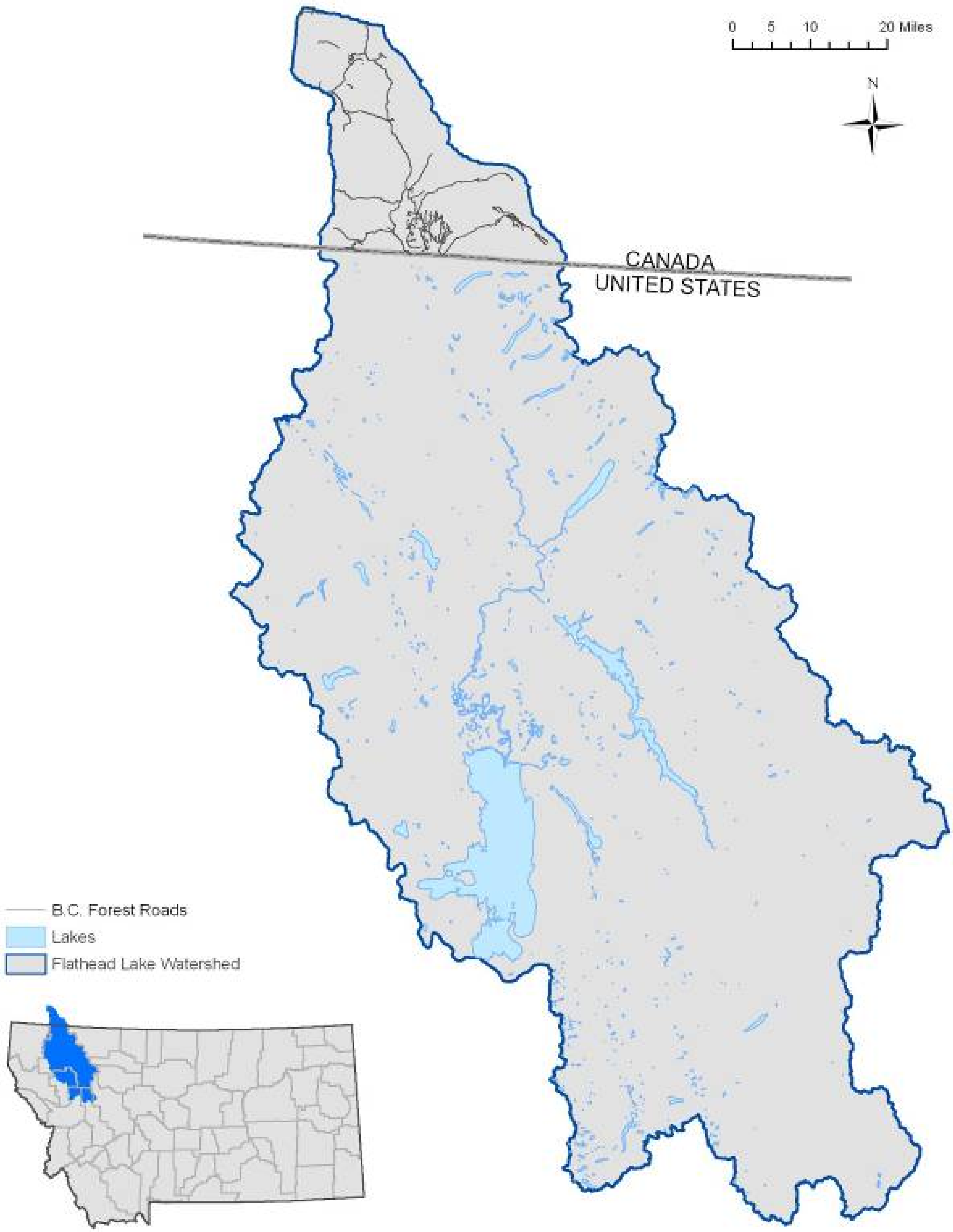

Figure 10. British Columbia Forest Roads in the Flathead Lake watershed.

3.11 CSKT

The Confederated Salish and Kootenai Tribe (CSKT) was contacted on July 15, 2008 to obtain roads data for tribal owned lands. At the time of this memo, no data were provided. It appears that a portion of the tribal roads appear in the Lake County and ITSD GIS data (discussed in Sections 3.6 and 3.2).

3.12 Plum Creek Timber Company

Plum Creek Timber Company was contacted on March 24, 2008 to obtain roads data for company owned lands. Plum Creek indicated that company owed roads in the Swan River basin were jointly mapped with the USFS roads, and Plum Creek roads in that basin are contained in the USFS roads coverage that is discussed in Section 3.3 (Personal communications, Brian Sudgen, March 24, 2008). Other data from Plum Creek is considered proprietary, and Plum Creek needs more information on the use of their data before releasing it to EPA or DEQ (Personal communications, Brian Sudgen, December 12, 2008).

3.13 Roads Summary

Ten GIS coverages were downloaded and evaluated for use in the Flathead Lake watershed. 0 summarizes the various coverages, the attributes included in those coverages, and the total number of road miles.

Table 10. Summary of road data for the Flathead Lake watershed.

Agency/Road Coverage	Publication Date	Area Covered	Surface Info	Width Info	Use Info	# of Miles	Qualitative Assessment
U.S. Census Bureau TIGER Roads	July, 2007	Entire watershed			✓	7,383	The TIGER roads were derived from 1:100,000 scale topo maps, and appear to have positional/ digitizing errors throughout the watershed. Furthermore, the shapefile does not include all of the known Forest Service roads. Because of positional errors, lack of data in the forests, and other more comprehensive coverages, the TIGER data is not recommended for use in the analysis.
ITSD Transportation Framework	February 15, 2007	Entire watershed	✓			9,019	The ITSD roads network was compiled from various data sources, including county roads and forest service roads. As a single coverage, it is the most comprehensive in the watershed. However, the individual road coverages from the respective agencies are more up to date, and it is recommended that they be used instead of the ITSD coverage.
Flathead National Forest Roads	February 27, 2008	Entire watershed, mostly Flathead National Forest lands (but some other land as well)	✓		✓	5,962	The FNF coverage is the single most comprehensive coverage for forest service lands. It is relatively up to date (2005), and includes multiple attributes that will be useful in the roads analysis. This coverage should be used to represent roads in the FNF. It should be noted, however, that private land interspersed within the forest service land is not well represented.
Glacier National Park Roads	January 1, 2008	Glacier National Park	✓		✓	240	The GNP coverage is the most comprehensive up to date coverage in the park. It should be used to represent the Park Service roads.
Flathead County Roads	March 26, 2008	Flathead County	✓	✓		3,570	The Flathead County roads coverage is the single most comprehensive and accurate coverage for the county. It is more up to date than the ITSD coverage. The county coverage has the best resolution data for the urban areas, but it lacking in the Forest Service areas. For this reason, this coverage should be merged with the FNF coverage to make one master file.
Lake County Roads	January 15, 2007	Lake County	✓		✓	1,289	The Lake County roads coverage is the single most comprehensive and accurate coverage for the county. It is more up to date than the ITSD coverage. The county coverage has the best resolution data for the urban areas, but it lacking in the Forest Service areas. For this reason, this coverage should be merged with the FNF coverage to make one master file.
Missoula County Roads	March 7, 2008	Missoula County				578	The Missoula County roads coverage is the single most comprehensive and accurate coverage for the county. It is more up to date than the ITSD coverage. The county coverage has the best resolution data for the urban areas, but it lacking in the Forest Service areas. For this reason, this coverage should be merged with the FNF coverage to make one master file.

Agency/Road Coverage	Publication Date	Area Covered	Surface Info	Width Info	Use Info	# of Miles	Qualitative Assessment
DNRC	October 18, 2006	State Owned Lands				1,107	The DNRC coverage is the single most comprehensive coverage for lands managed by DNRC. It contains no road surface data. Some of the data is included in other roads coverages; however, certain areas are unique and not contained in any other coverage. For this reason, this coverage (or portions of it) should be included in the analysis.
British Columbia National Road Network	Unknown	British Columbia	✓		✓	112	The B.C. Roads network is duplicated in the B.C. Forest Roads coverage. Therefore, this coverage is redundant.
British Columbia Forest Roads	Unknown	British Columbia	✓		✓	236	The B.C. Forest Roads coverage is the most comprehensive coverage available at the time of this report. However, it is believed to be missing a significant # of logging roads. A request has been placed with B.C. to obtain additional data.

As shown in Table 10, there are a variety of roads datasets for the Flathead Lake watershed. It would appear that the ITSD coverage contains the most comprehensive coverage for the entire watershed (except for British Columbia). However, upon further inspection, the ITSD coverage is not complete; a comparison to other coverages shows that there are numerous roads not captured by the ITSD coverage (see Figure 11). Furthermore, the ITSD coverage contains limited information on road surfaces (only 53% of the road miles have surface information).

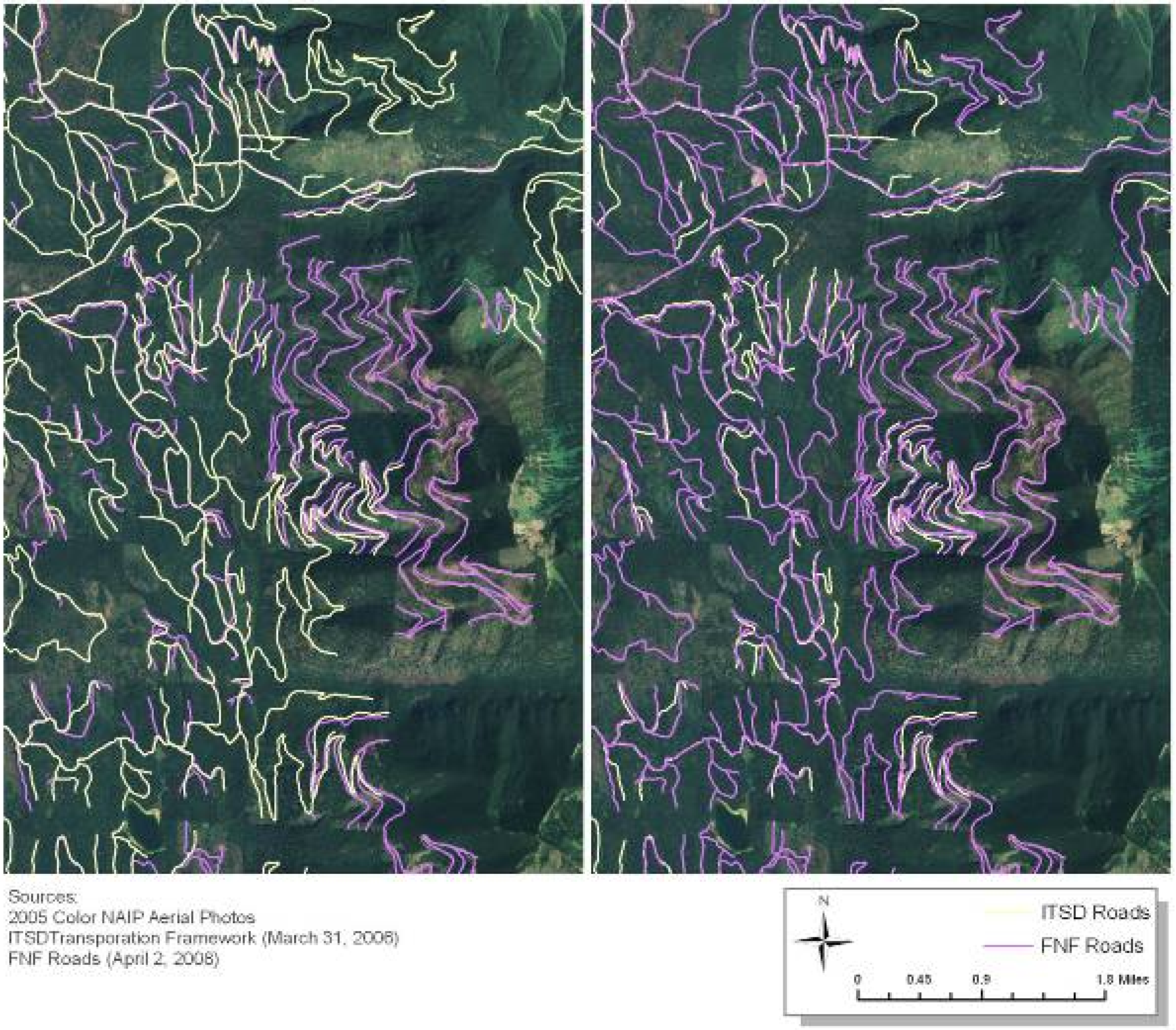

Figure 11. Comparison of the ITSD and Flathead National Forest Roads (Goat Creek subbasin in the Swan River watershed). Note that both coverages contain roads not included in the other.

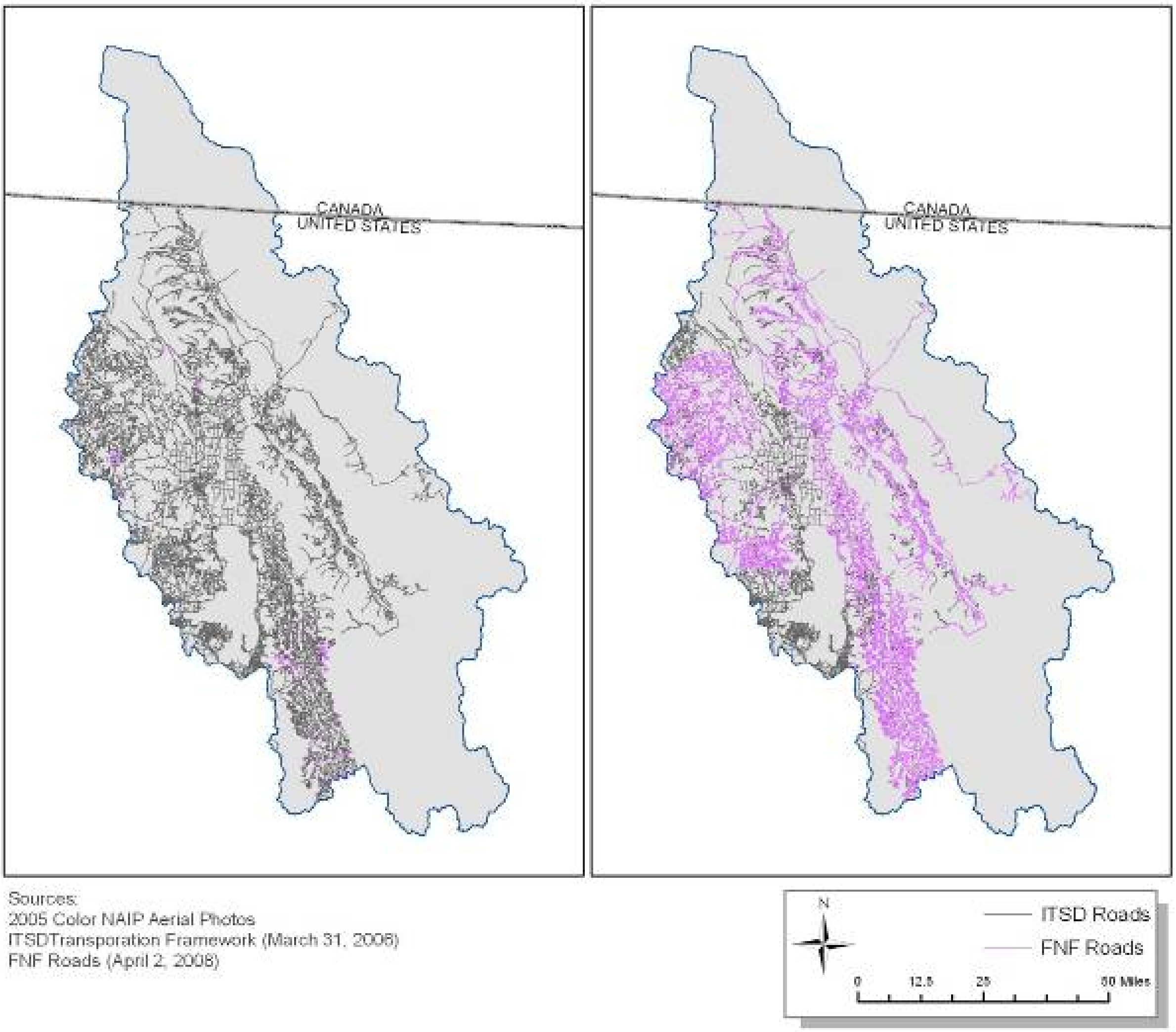

Figure 12. Comparison of the ITSD and Flathead National Forest Roads. Note that both coverages contain roads not included in the other. However, the ITSD coverage contains most of the FNF roads (left map above), although not as many attributes.

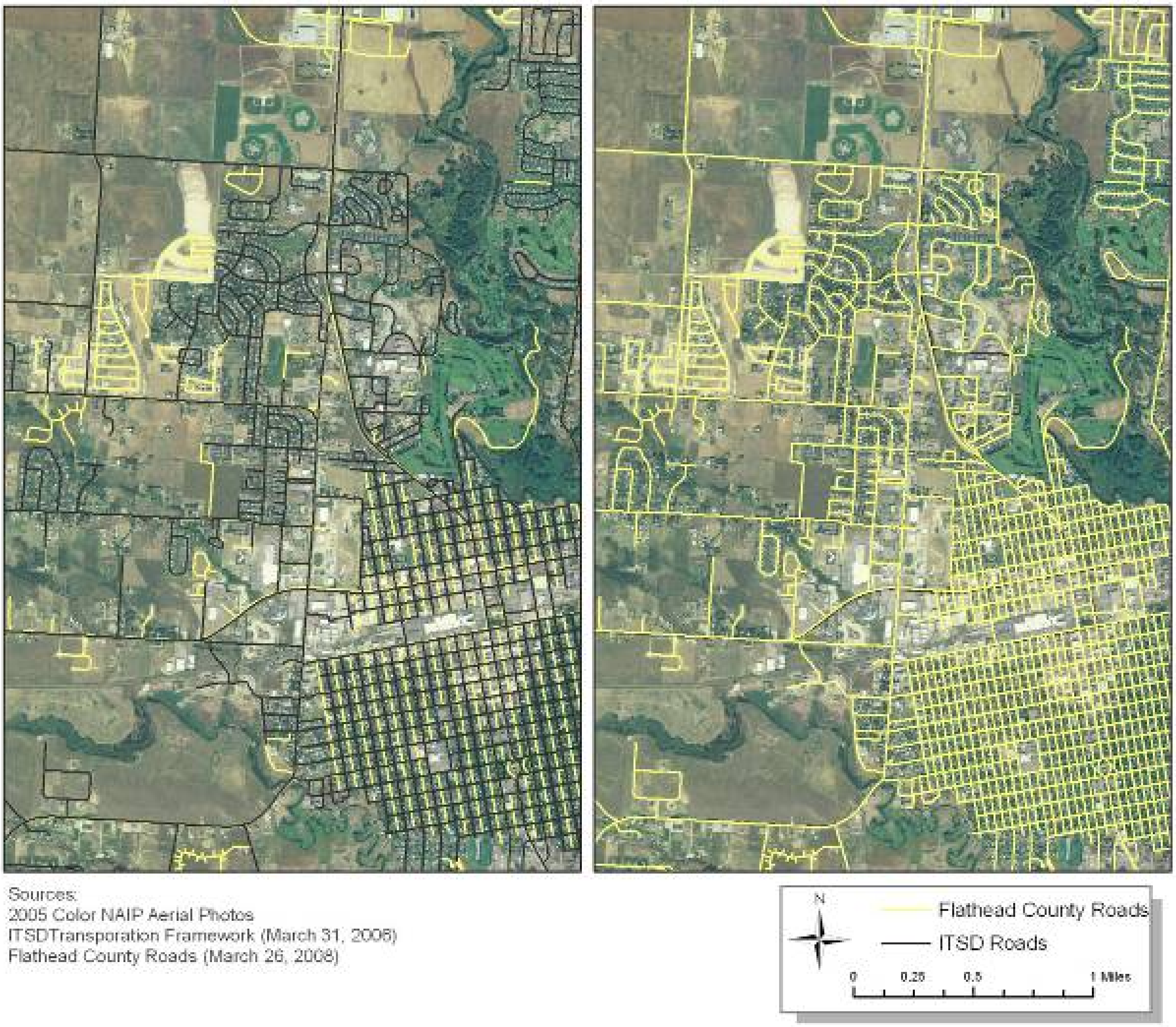

Figure 13. Comparison of the ITSD and Flathead County Roads (northwest corner of Kalispell). Note that the Flathead County Roads coverage is more up to date, showing new roads/subdivisions northwest of Kalispell. Also note that the Flathead County roads coverage shows alleys not included in the ITSD coverage.

4.0 Compilation of Roads Data

A comprehensive roads coverage (i.e., the “Master” roads coverage) was created using the data discussed in Section 3.3 through 3.12. Segments from each coverage were compiled and merged into a “master” roads coverage for the Flathead Lake watershed (Figure 14). The following sections describe the methodology for creating the master roads coverage.

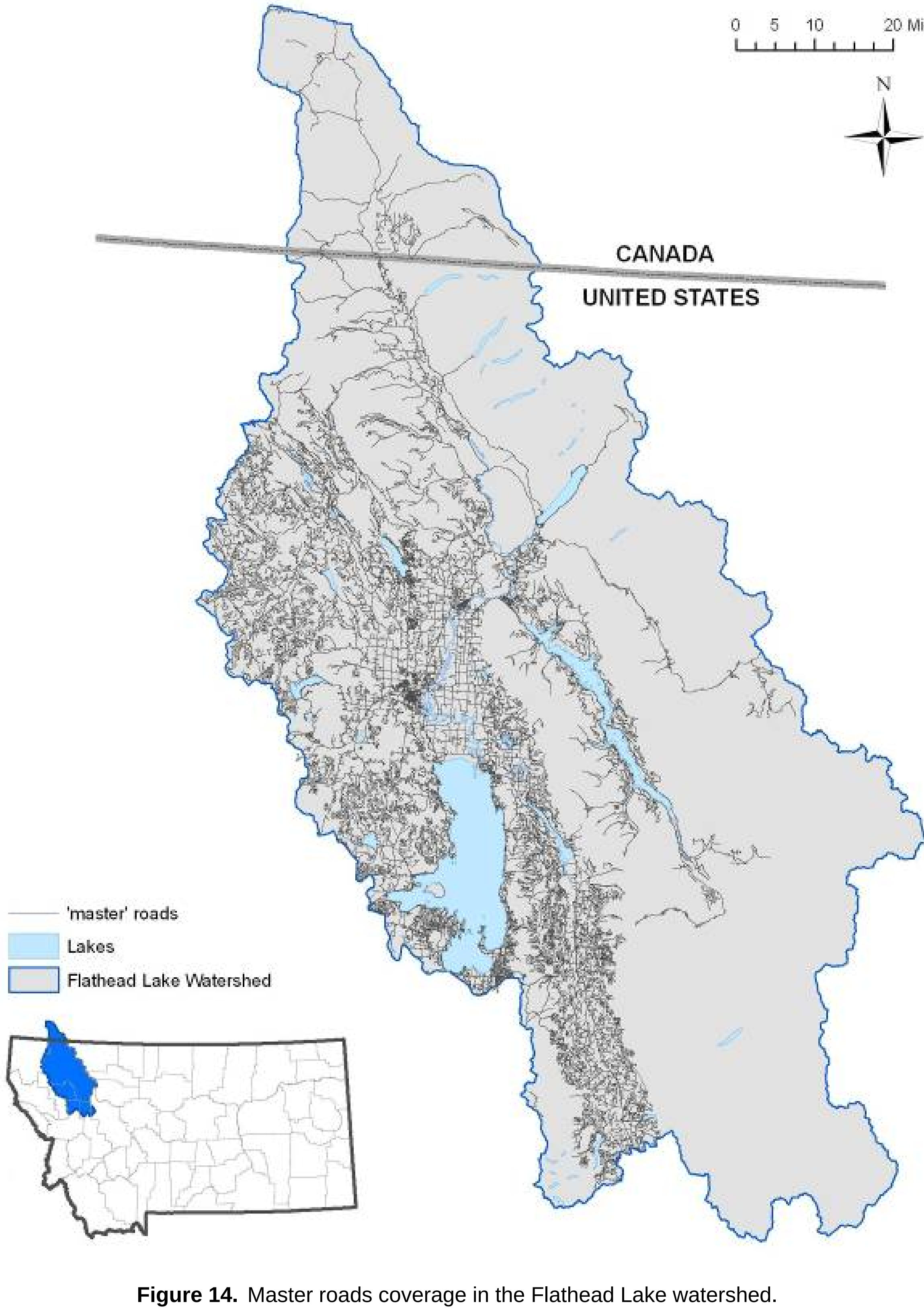

Figure 14. Master roads coverage in the Flathead Lake watershed.

4.1 Preparing Data for Analysis

The goal of this exercise was to combine the roads from various GIS coverages to create a single coverage containing all of the known roads without any duplicates. As described in 3.13, the most up-to-date roads data for the Flathead Lake watershed are the Flathead National Forest and county data. Other GIS coverages containing unique data include the DNRC, GNP, and B.C. data.

Data processing began with the FNF roads coverage. The FNF roads coverage encompassed parts of Lake, Lincoln, and Missoula Counties and all of Flathead County. The FNF coverage was clipped into 4 separate coverages – one for each county. Due to various software and hardware limitations, Flathead County was then divided into quadrants named Alpha, Beta, Gamma, and Delta (see Figure 15). The Flathead County portion of the FNF data and the Flathead County data were clipped to these quadrants.

Roads in two small areas in the ITSD Transportation Framework from the Flathead Indian Reservation and the Kootenai National Forest were not present in any other coverage. Therefore, the roads in these areas (see Figure 16) were included in the analyses. A unique methodology was used to include this data in the final output (see Section 4.2).

All of the data from British Columbia and the Lincoln County portion of FNF were unique, and, thus, no additional analysis or modification was necessary. The GNP, DNRC, and a portion of the ITSD data were modified using a unique methodology, which is discussed in Section 4.3.

Each of the remaining clipped coverages were individually dissolved (*ArcToolbox: Data Management Tools: Generalization: Dissolve*) and saved as a new shapefile. The dissolved coverages were then divided into 100m segments (*Editor Tool Bar: Divide*, set to 100 units and select “delete selected feature”) to create a uniform segment length among all of the coverages. Next, the segments were converted into unique lines (*ArcToolbox: Data Management Tools: Features: Split Line at Vertices*) and saved as a new shapefile. Finally, the original attribute data was spatially joined to the segmented coverage (*ArcToolbox: Analysis Tools: Overlay: Spatial Join*) and saved as a new shapefile.

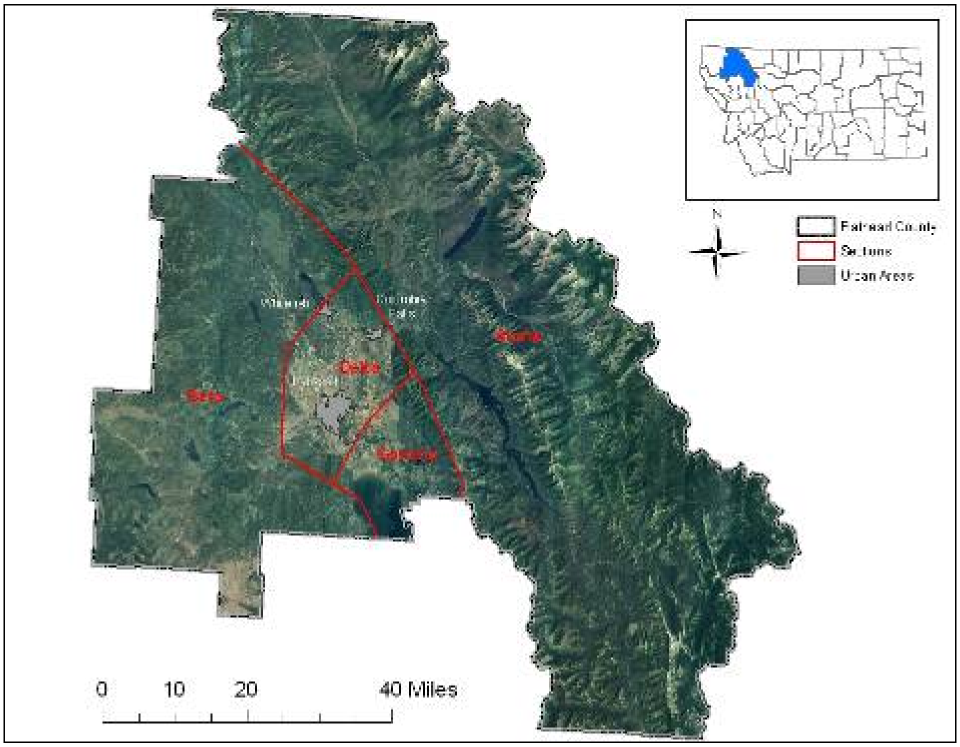

Figure 15. Flathead County quadrants.

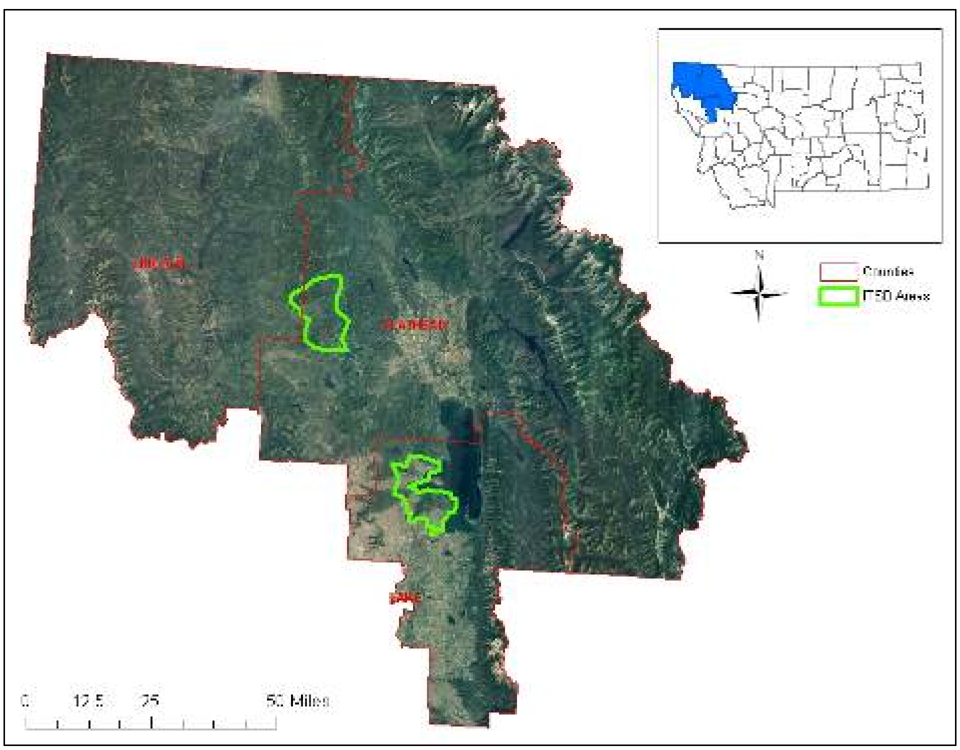

Figure 16. Location of unique roads in the ITSD GIS coverage.

4.2 Data Analysis

The ArcScript MatchStix (MatchStix 2.0, released August 2004) was used to determine similarities between roads coverages. MatchStix is an ArcScript that compares the line segments from one coverage ('source') to the line segments of coverage ('target') so as to determine whether or not segments from the 'source' are unique with respect to the 'target'.

The MatchStix metadata describes the ArcScript as follows:

> *MatchStix is like ArcInfo Workstation's MatchCover. You use it to find features in one layer (source layer) that have almost identical geometry to features in another layer (target layer). The result is a dbf table containing the objectids of the matching source and target layers. You can use this table to make selections against one or both layers for further analysis or conflation activities* (Krouk 2004).

MatchStix was executed for six pairings of shapefiles:

1. Missoula County and FNF's Missoula County portion
2. Lake County and FNF's Lake County portion
3. Section Alpha: Flathead County and FNF's Flathead County portion
4. Section Beta: Flathead County and FNF's Flathead County portion
5. Section Gamma: Flathead County and FNF's Flathead County portion
6. Section Delta: Flathead County and FNF's Flathead County portion
7. Summation of 1-6 and ITSD.

In the first six pairings, the FNF data was input as the 'source' and the County data was inputted as the 'target'.

The ArcScript requires the user to input a tolerance distance that the program will use when searching for similar vertices. The tolerance is the distance around the location of a 'source' vertex that MatchStix will search for a 'target' vertex in the 'target' coverage. If each of the beginning and ending vertices from the 'target' segment are located within the tolerance distance of the beginning and ending vertices from the 'source' segment, then MatchStix records the two segments as the same. However, if MatchStix cannot locate one or both of the 'target' vertices within the tolerance distance of the location of the 'source' vertices, then the segments are recorded as unique.

In order to determine what level of tolerance to use, the ArcScript was executed using a tolerance of 50 meters and 100 meters for the Lake and Missoula County pairings. In both cases, the 50 meter tolerance was chosen for the final output; therefore, only the 50 meter tolerance was used for the rest of the pairings.

After the ArcScript was executed, MatchStix created a DBF file that displays the results. The DBF file listed the 'source' segments ("SrcOID") and 'target' segments ("TrgtOID") that were equivalent. This DBF file was joined to one of the two input files.

For pairings #1 and #2, the shapefiles using a 50 meter tolerance and 100 meter tolerance were compared. Both tolerances yielded more unique roads in some areas and less unique roads in other areas. The 50 meter tolerance was chosen because it captured greater portions of segments not included in one roads coverage (Figure 17 through Figure 19). However, in some areas, this tolerance also captured road segment that were actually the same road but had been digitized differently between the two original coverages.

Figure 17. Example of original roads coverages

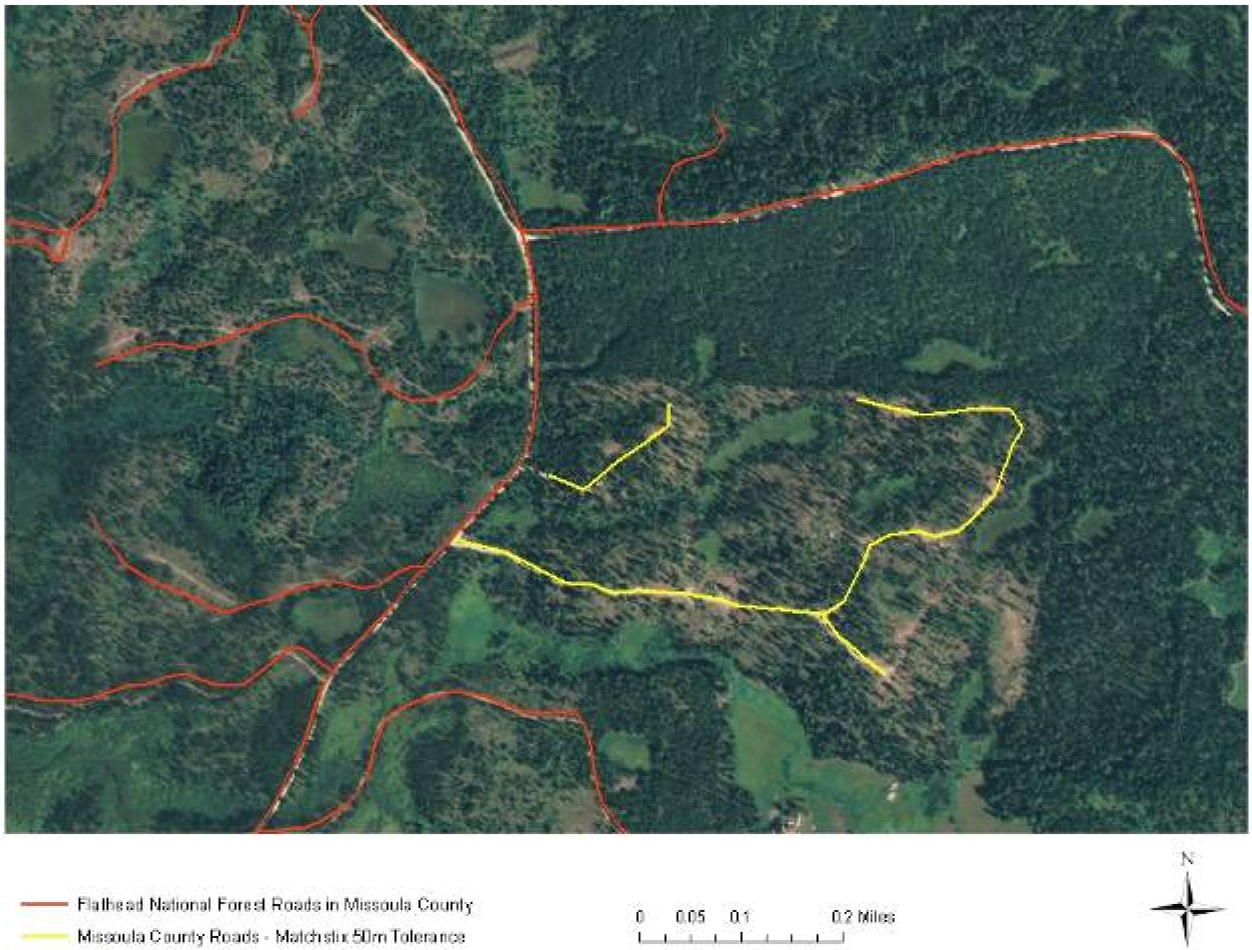

Figure 18. Example of unique segments from MatchStix output using 50 meter tolerance. Note how the smaller Missoula County segment does not intersect with the FNF segment

Figure 19. Example of unique segments from MatchStix output using 100 meter tolerance. Note how both Missoula County segments do not intersect the FNF segment

After displaying and visually verifying the 'unique segments' shapefile, the shapefile was merged with the shapefile that did not contain these segments. Thus, the unique data from one shapefile was merged with the other shapefile to yield a shapefile with all roads contained within the two originally inputted shapefiles. Each of the seven pairings resulted in merged shapefiles.

4.3 Compilation of Final Dataset

The master file was created using the seven pairings and the four datasets not run through MatchStix. Due to software and/or hardware limitations, the master file was incrementally created by merging one file at a time with the master file. The Lake and Missoula County pairings were merged first and then the Lincoln County portion of the FNF and British Columbia data were each separately merged into the master file. Next, the GNP data was added. There were only a few segments in the GNP coverage that were not identical to the third merged pairing (Alpha sections) discussed above. These segments were manually selected, exported as a new shapefile, and merged with the master file. Then, the Flathead County section pairings were merged. The last additions were the DNRC data and a subset of the ITSD data. The DNRC segments were manually selected, exported as a new shapefile, and merged with the master.

ITSD segments were also added following the methodology used for GNP and DNRC data, with the exception of the two areas shown in Figure 16 that were added following the MatchStix methodology.

4.4 Quality Control

The entire preprocessing methodology was performed on the Missoula County data a second time to ensure that the GIS software was operating consistently. The quality control (QC) preprocessing yielded the same outputs as the original preprocessing; for example, in both cases, the same number of records was yielded (16,799). The outputted shapefiles for each step were visually compared to one another and found to be identical. Finally, the MatchStix ArcScript was run on the original and QC outputted shapefiles from the attribute spatial join step. A tolerance of 0 meters was used and MatchStix outputted a DBF that showed that all corresponding segments were equal (i.e. the two coverages were identical).

The operational consistency of MatchStix ArcScript was also verified. MatchStix was run on the QC preprocessing output and Missoula County portion of the FNF data preprocessing output. The resultant DBF was identical to the DBF yielded during the original pairing (pairing #1). Both DBF outputs yielded 43,942 segment pairing comparisons and the SrcOID's and TrgtOID's were identical (both fields were sorted and 30 corresponding segments throughout the DBF were verified).

The accuracy of the master file was tested by overlaying the file upon the 2005 U.S. Farm Services Agency National Agricultural Imagery Program (NAIP) 1-meter images for Montana (available at http://maps.nris.mt.gov). The aerial photos were used to digitize roads for 10 individual Sections in the Flathead Lake watershed – six Sections were selected to evaluate areas with known road errors, and four Sections were chosen at random. The sections including Polson and Kalispell were selectively chosen to represent developed cities and urbanized areas; whereas, the rural area north of Somers was selectively chosen to represent rural and country areas. The sections including Plum Creek timberland and F.H. Stoltze timberlands were selectively chosen to represent privately owned forest land. The section including GNP was selected to represent the scarcity of roads in the National Park.

A roads validation exercise was then completed for 10 Sections (i.e., square miles) in the Flathead Lake watershed (i.e., <1 percent of the watershed). Five of the Sections were randomly selected and five were selected to target areas where it was suspected that the available roads data may be limited and/or inaccurate. As shown in Table 11, the exercise shows that, on average (for all 10 Sections), the GIS coverage captured 79 percent of the roads existing in the 2005 aerial photos (range of 34% to 110% of the roads captured). For the randomly selected validation sections, the GIS coverage captured 94 percent of the roads. For the validation sections targeted as suspected problem areas, the GIS coverage captured 68 percent of the roads. The reasons for the discrepancies appear to be:

- Missing GIS data for large tracks of private lands (e.g., Stoltz and Plum Creek owned lands)
- Missing GIS data for rural driveways and two-track roads.

- Scale and digitizing discrepancies in the GIS data.
- Outdated aerial photos (i.e., 2005 photos versus 2007/2008 GIS data).
- Difficulties in interpreting the aerial photos.
- Errors in compiling and processing the master roads coverage.

Comparisons of the GIS roads coverage to the aerial photos are presented in Figure 20 through 29.

Table 11. Accuracy analysis of the master roads file

Town-ship	Range	Section	Landscape or location	Aerial imagery (miles)	Master GIS Coverage (miles)	% Captured in the GIS Coverage (%)[2]	Qualitative Assessment
23N	20W	30	Polson[1]	8.71	6.34	73%	Most of the roads that are missing from the master coverage are driveways to rural homes, and small, two-track roads through rural ranches.
24N	21W	3	Dayton	6.75	5.77	85%	Most of the roads that are missing from the master coverage are driveways to rural homes, and small, two-track roads through rural ranches.
25N	19W	10	FNF	4.22	4.32	102%	A large portion of this section has been extensively clear cut. This is obvious when comparing the old (1980s) aerial photos to the 2005 aerial photos. It is difficult to determine if old timber harvest roads that were obvious in the 1980s photo are still present or have been decommissioned. This is the reason that there is excess mileage in the Master Roads Coverage – more roads were present than appear to be in the 2005 aerial photo. Also, the digitizing in this region is generally poor – line segments do not match the aerial photos well.
27N	21W	11	Rural, north of Somers[1]	5.99	3.16	53%	Most of the roads that are missing from the master coverage are driveways to rural homes, and small, two-track roads through rural ranches.
28N	22W	12	Kalispell[1]	13.05	9.03	69%	This section is in a developed and recently developing region near the City of Kalispell. Most of the missing roads are urban and rural driveways and alleys. It should be noted that there are some roads in the GIS coverage that are not in the aerial photo because of recent development (post 2005).
28N	24W	27	Plum Creek timberlands[1]	8.77	7.66	87%	This section has had extensive timber harvest in the past 5 to 10 years. Numerous forest roads are evident. However, it is difficult to distinguish between roads and skid trails in the aerial photo, and the number of miles determined from the aerial photo may be overestimated.
29N	17W	8	FNF	2.89	2.33	81%	There are very few roads in this section. Most of the roads are captured expect for small errors due to the Matchstix process.
29N	24W	9	FNF	4.09	4.51	110%	This Section has had extensive timber harvest. Some roads that are contained in the GIS coverage do not appear to exist anymore, or have been extensively overgrown by the tree canopy.
31N	21W	11	F.H. Stoltze timberlands[1]	5.49	1.89	34%	This section is privately owned, and it appears that roads data simply have not been obtained and input into the FNF or Flathead County GIS coverages.
33N	19W	27	GNP[1]	1.98	1.98	100%	All roads are capture in this section.

[1] Area was selected to target problem areas.

[2] The percentage of captured roads does not reflect accuracy because the GIS coverage may contain accurate roads that are not contained in the aerial photography (which were obtained in 2005). Also, the GIS coverage may contain roads that are not present in one region, only to be offset by missing roads in another region.

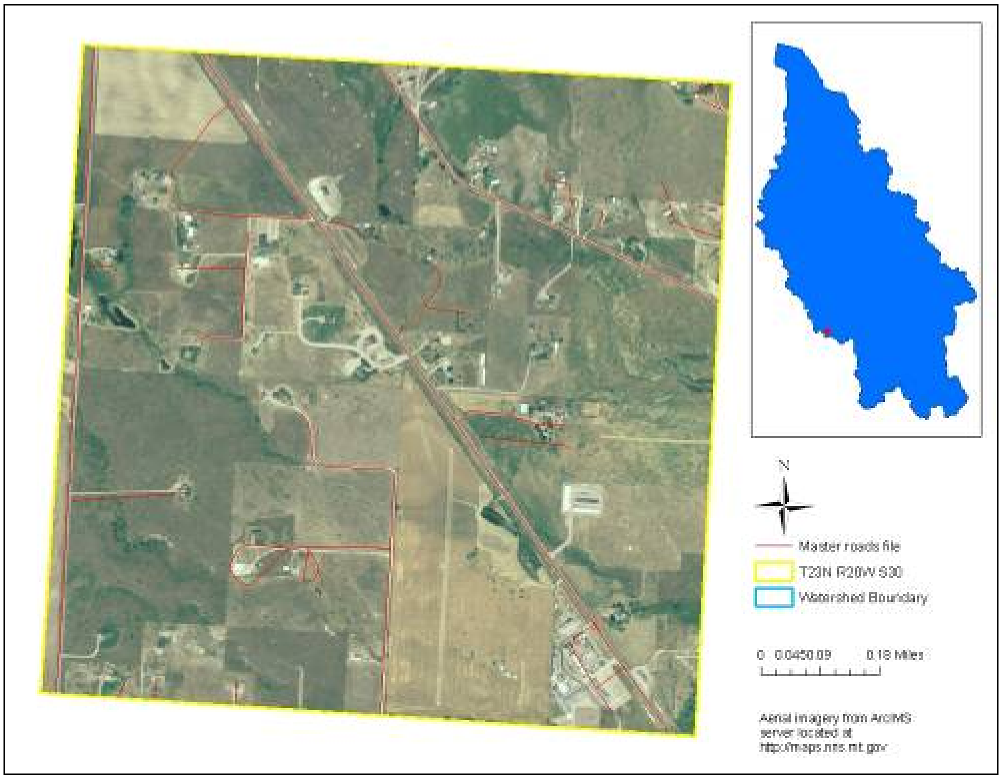

Figure 20. Quality control for T23N R20W S30.

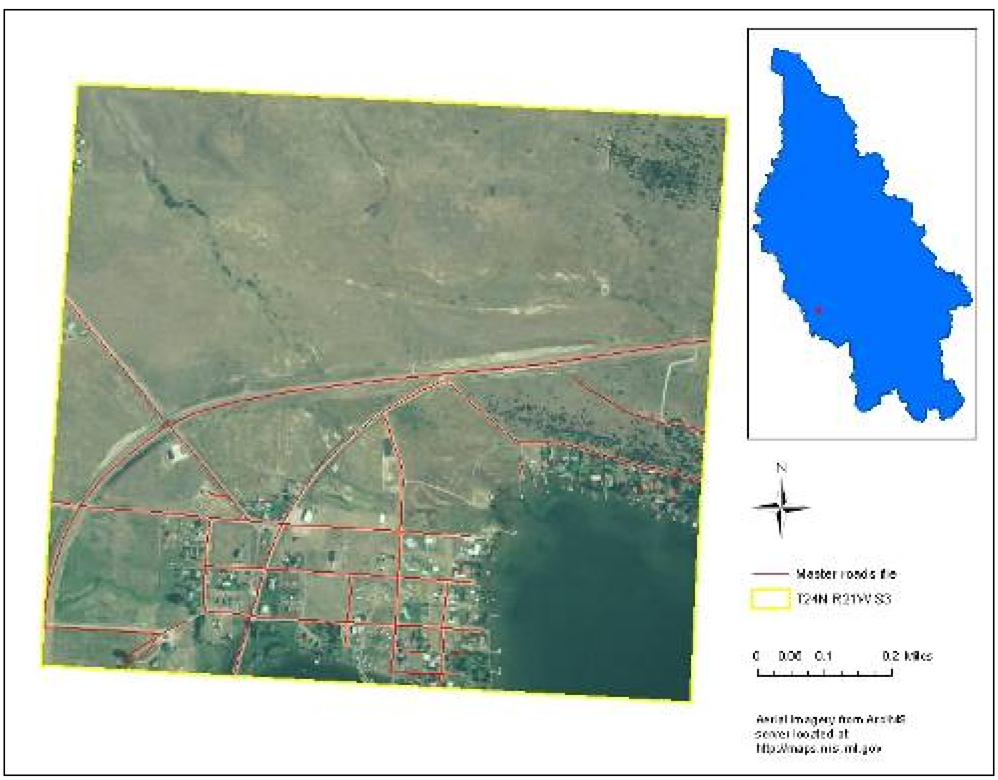

Figure 21. Quality control for T24N R21W S3.

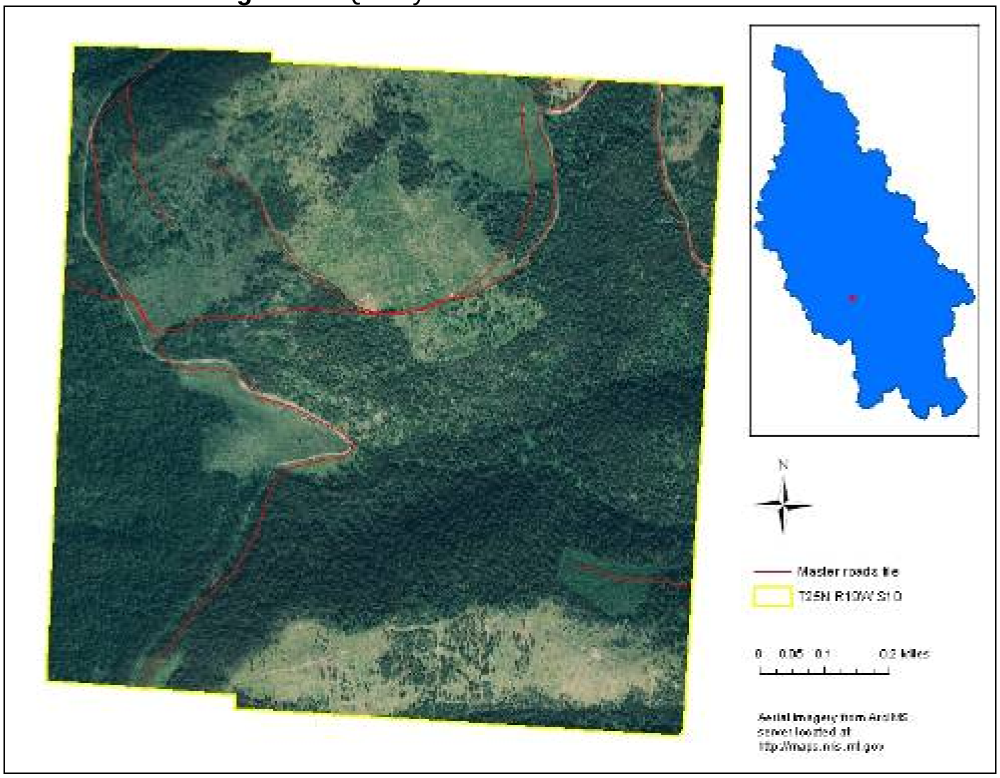

Figure 22. Quality control for T25N R19W S10.

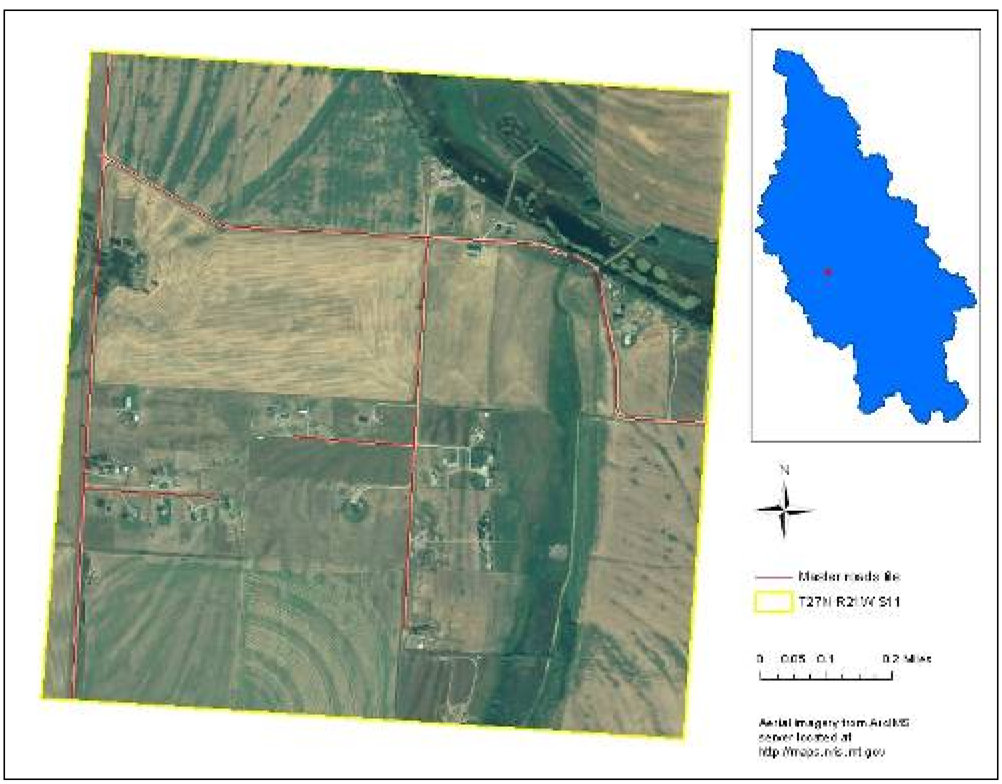

Figure 23. Quality control for T27N R21W S11.

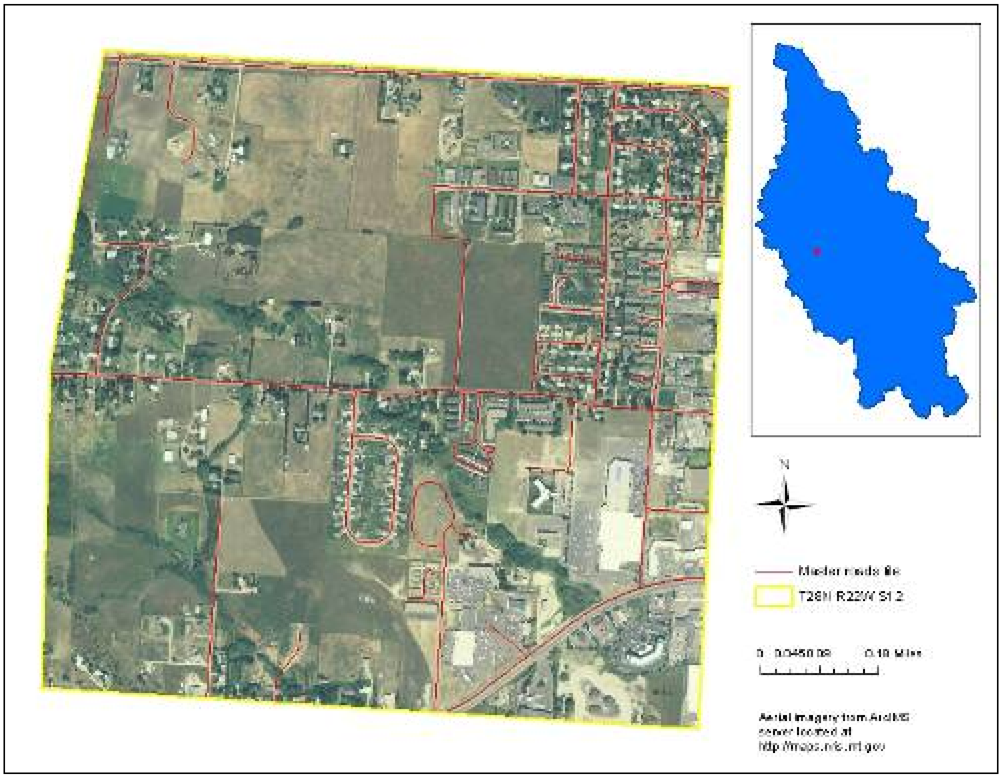

Figure 24. Quality control for T28N R22W S12.

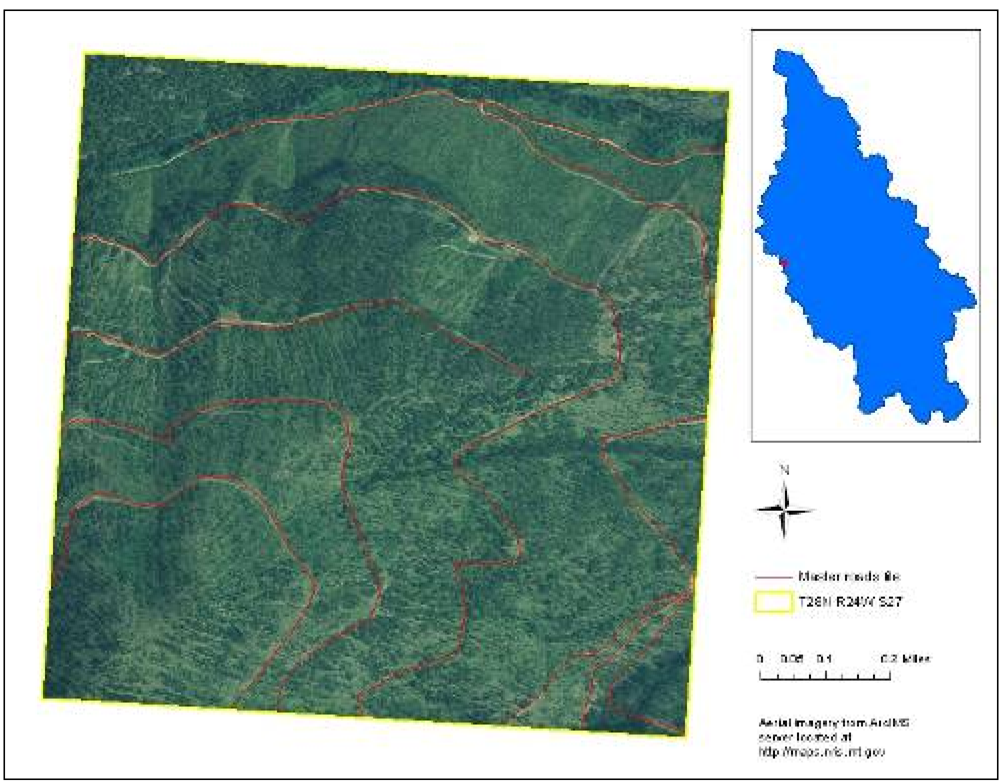

Figure 25. Quality control for T28N R24W S27.

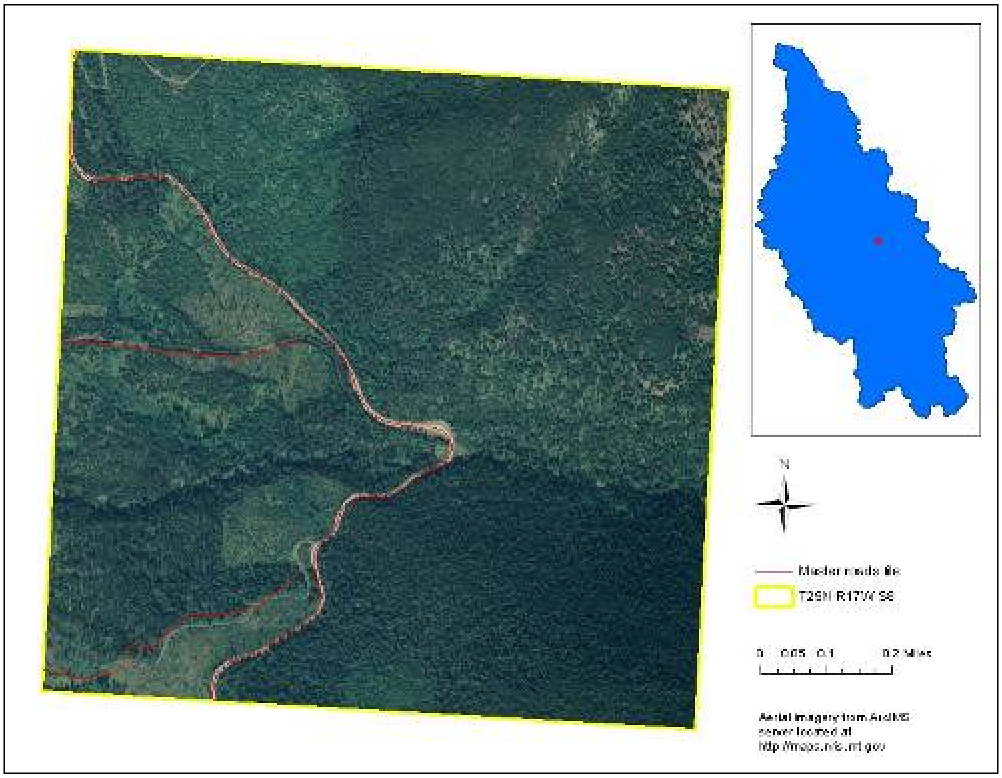

Figure 26. Quality control for T29N R17W S8.

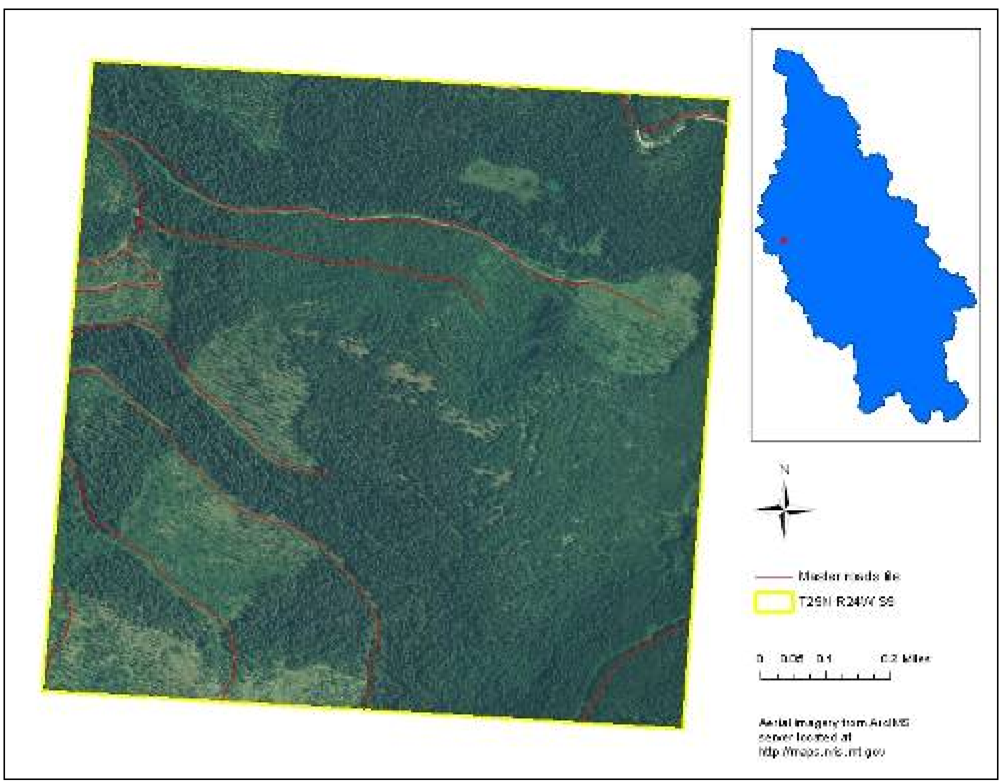

Figure 27. Quality control for t29N R24W S9.

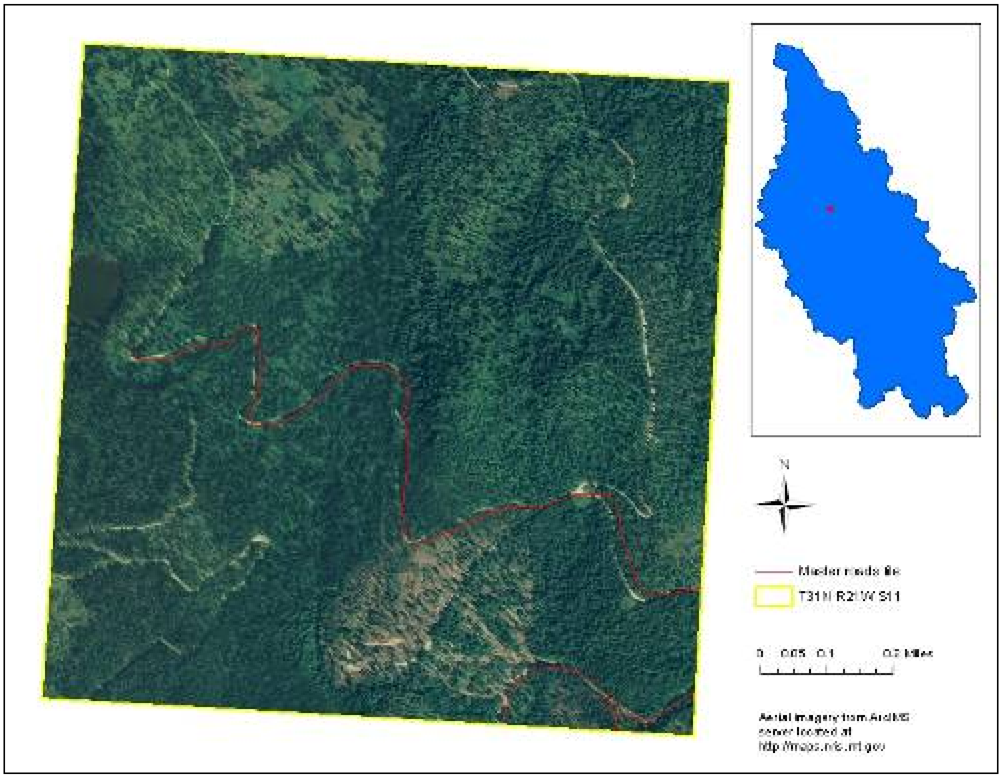

Figure 28. Quality control for T31N R21W S11.

Figure 29. Quality control for T33N R19W S27.

5.0 Roads Summary

Roads are suspected to be one of the larger sources of sediment in the Flathead Lake watershed. Because of this, it is important to understand the location and type of roads in the watershed to facilitate modeling and TMDL development. Ten road GIS coverages were evaluated to determine their suitability for use in modeling and TMDL process. Each coverage had a unique subset of roads and attributes, but no one coverage contained all of the known roads.

A comprehensive roads coverage was therefore created in a GIS using roads data from state, county, and federal agencies. The master coverage was created by using the most accurate and representative data for the region. The resulting roads coverage (shown in Figure 14) is a compilation of unique subsets of road segments from selected roads coverages yielding a final total distance of 10,201 miles of roads. Table 12 displays the type of road surfaces in miles for the master roads coverage.

Table 12. Summary of road surface and miles for the master roads coverage.

Description*	Road Length (miles)
Asphalt	0.75
Crushed Aggregate & Gravel	765
Bituminous Surface Treatment	0.02
Dirt	28
Gravel	148
Native Material	3,402
Natural	362
Paved	1,420
Unknown	4,076
Total**	**10,202**

The "master" roads coverage is more comprehensive, accurate, and up-to-date than any other single coverage for the region. The "master" coverage contains 10,202 miles of roads with 6,126 miles of roads having surface pavement attribute data. This is 13 percent more roads than the next highest density roads coverage (ITSD – 9,019 miles). Also, the master coverage contains more accurate and current roads reflecting 2007 and some 2008 road additions in some areas. In lieu of a complex aerial photo interpretation and digitization effort, the generated master coverage is believed to be the most comprehensive coverage available for the Flathead Lake watershed.

6.0 Data Gaps

At the time of this report, several data gaps existed in the roads data. Specifically, roads GIS data was not available from the CSKT and major private land owners in the watershed (such as Plum Creek or F.H. Stoltze). Also, several roads coverages (e.g., Flathead National Forest Roads) did not have recent road information (for example, the publication date of the FNF coverage is 2005).

7.0 References

Anderson, H.W., M.D. Hoover, and K.G. Reinhart. 1976. Forests and Water: Effects of Forest Management on Floods, Sedimentation, and Water Supply. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. General Technical Report PSW-018. Berkeley, CA: 115 p.

Brown, G.W. and J.T. Krygier. 1971. Clearcut logging and sediment production in the Oregon Coast Range. *Water Resources Research* 7(5):1189-1198.

Cederholm, C. J., L. M. Reid, and E. O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Presented to the conference Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest? October 6-7, 1980. Seattle, WA. 35 pp.

CWP. 2003. Impacts of Impervious Cover on Aquatic Systems. Center for Watershed Protection Watershed Protection Research Monograph No. 1. Ellicott City, Maryland. Available online at http://www.cwp.org/pubs_download.htm.

DEQ. 2004. Water Quality Protection Plan and TMDLs for the Swan Lake Watershed. Montana Department of Environmental Quality.

Elliot, W.J., D.E. Hall, and D.L. Scheele. 2000. Disturbed WEPP (Draft 02/2000) WEPP Interface for Disturbed Forest and Range Runoff, Erosion and Sediment Delivery Technical Documentation. U.S.D.A. Forest Service Rocky Mountain Research Station and San Dimas Technology and Development Center. Available online at http://forest.moscowfsl.wsu.edu/fswepp/docs/distweppdoc.html (Accessed April 24, 2008).

Flathead County. 2006. GPS Roads [Computer File]. Flathead County GIS Department (Producer and Distributor). Kalispell, Montana. Available online at http://maps.co.flathead.mt.us/. Accessed March 26, 2008.

Fredrickson, R.L. 1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. U.S.F.S. Res. Paper. PNW and Range Exp. Sta., No. PNW-104.

Gardner, Beth. 2000a. Baseline condition for bull trout: Stillwater River Drainage, including disjunct populations of Tally Lake, Upper Stillwater Lake, Whitefish Lake, and Upper Whitefish Lake. Flathead National Forest, Tally Lake Ranger District. April 2000.

Gardner, Beth. 2000b. Baseline condition for bull trout: Swan River Drainage, including disjunct populations of Holland Lake and Lindbergh Lake. Flathead National Forest, Swan Lake Ranger District. May 2000.

GNP. 2008. Roads in Glacier National Park [Computer File]. Glacier National Park (Producer and Distributor). West Glacier, Montana.

Gucinski, Hermann, Michael J. Furniss, Robert R. Ziemer, and Martha H Brookes. 2001. Forest Roads: A Synthesis of Scientific Information. General Technical Report PNW-GTR-509. Forest Service Pacific Northwest Research Station. US Department of Agriculture.

Hagans, D. K., W. E. Weaver, and M. A. Madej. 1986. Long term on-site and off-site effects of logging and erosion in the Redwood Creek basin, Northern California. In: Papers presented at the American Geophysical Union meeting on cumulative effects (1985 December); National Council on Air and Streams, Tech.Bull.No. 490, pp.38-66. 29 pp.

Hammer, K.J. 2004. Watersheds at Risk: Roads Threaten Bull Trout on the Bitterroot, Flathead and Lolo National Forests. Swan View Coalition.

Lake County. 2007. Street Centerline Data for Lake County, MT [Computer File]. Flathead County Plat Room/GIS Department (Producer and Distributor). Polson, MT. Available online at http://www.lakecounty-mt.org/clerkrecorder/platroom.html

Missoula County. 2008. Missoula County Roads, Missoula County Public Works Department (Producer and Distributor). Missoula, Montana. Available online at http://www.co.missoula.mt.us/Mapping_GIS/index.asp. Accessed April 22, 2008.

Sheridan, Gary and Philip Noske. 2008. Accessed today via internet. Sediment generation and management from unsealed forest roads and tracks. Forest Science Centre, Department of Sustainability and Environment, PO Box 137 Heidelberg, Vic 3084, Australia.

Sugden, Brian D. and Scott W. Woods, 2007. Sediment Production from Forest Roads in Western Montana. *Journal of the American Water Resources Association* (JAWRA) 43(1):193-206.

Sugden, Brian D. 2010. Road Sediment Delivery Rates on Plum Creek Roads in the Flathead River Basin. Unpublished.

Taylor, Steven E.; Rummer, Robert B.; Yoo, Kyung H.; Welch, Richard A.; Thompson, Jason D. 1999. What We Know--and Don't Know--About Water Quality at Stream Crossings. *Journal of Forestry*, Vol. 97, No. 8,August 1999, pgs. 12-17.

U.S. Census Bureau. 2006. TIGER Frequently Asked Questions (FAQs). U.S. Department of Commerce, U.S. Census Bureau, Geography Division. Available online at http://www.census.gov/cgi-bin/geo/tigerfaq.

U.S. Census Bureau. 2007. 2007 TIGER/Line® Shapefiles for Flathead, Lake, Missoula, Powell, and Lewis and Clark Counties[Computer File]. U.S. Department of Commerce, U.S. Census Bureau, Geography Division [Producer and Distributor]. Available online at http://www.census.gov/geo/www/tiger/.

USFS. 2002. Flathead National Forest Meta Data for Roads (Background Information) (Dated June 14, 2002). Flathead National Forest. Kalispell, Montana.

USFS. 2008. Cartographic Feature Files (Lines). U.S. Forest Service – Pacific Southwest Region. Available online at http://www.fs.fed.us/r5/rsl/projects/frdb/layers/cffl.html.

Watson, Greg; Steve Toth; Brian Sugden; Paul Wetherbee; Ron Steiner; Matt O'Connor; John Woods; Dean Sirucek; Liz Hill; Carol Purchase; and Paul Callahan. 1998. Goat Creek and Piper Creek Watershed Analysis. Plumb Creek Timber Co., Missoula MT.

VanEimeren, Pat. 2000a. Baseline bull trout biological assessment for the North Fork and Middle Fork Flathead River Drainages. Flathead National Forest. May 2000.

VanEimeren, Pat. 2000b. Baseline bull trout biological assessment for the South Fork Flathead River Drainage. Flathead National Forest. May 2000.