Septic interpretations from a third order soil survey

by William Thomas Christner, Jr

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University

Abstract:
Demographic changes throughout the Rocky Mountain west are resulting in an increasing number of rural subdivisions away from city centers. Rural housing developments require on-site sewage disposal systems to handle household waste. Development of large tracts of formerly range and forest soils, has produced the need for septic system suitability information of these soils. Range and forest soils, typically covered by third order soil surveys, are not intended for septic interpretations. However, they may contain the data necessary for septic interpretations. The Gallatin Local Water Quality District (LWQD) in southwestern Montana contains portions of Gallatin Valley and Gallatin National Forest (GNF) soils within its boundaries. Gallatin Valley soils are lowland agricultural soils covered by a second order soil survey and have been interpreted for on-site sewage disposal systems. GNF soils are higher elevation range and forest soils covered by a third order soil survey and are not interpreted for on-site sewage disposal systems. The Gallatin LWQD provides the opportunity to determine if the third order GNF soil survey contains the data necessary for septic system interpretations. This case study also provides the opportunity to compare septic interpretations from second order GallatinValley soils to septic interpretations from corresponding third order GNF soils along the Gallatin Valley/GNF border.

Initial investigation of the third order GNF soil survey provided data regarding the septic limitations of GNF soils. Septic interpretations based on the most-limiting restriction were made for each GNF soil map unit. An ArcView™ coverage of the most limiting septic restriction for GNF soils was constructed and compared to the corresponding Gallatin Valley coverage along the Gallatin Valley/GNF border. Initial results showed poor agreement between septic interpretations of corresponding Gallatin Valley/GNF border map units based on the most-limiting restriction.

Complete septic interpretations (slight, moderate and severe) for all restrictions were compared between corresponding Gallatin Valley/GNF border map units. Results showed a high percent match (73%) between the complete septic interpretation of corresponding Gallatin Valley/GNF border map units. These results were consistent in a refined comparison that weighted each GNF map unit according to its percent match with its corresponding Gallatin Valley map unit. This method produced a 75 percent match.

Septic interpretations based on observations from twenty-four field soil pits suggested that restrictions with high percent match results were favored by a high number of map units with “slight” limitations. Comparisons based on a broad range of limitation data (slight, moderate and severe) showed higher agreement with GNF data than Gallatin Valley data ($p = 0.74$ vs. 0.65 respectively). I found that although the third order GNF soil survey was not designed for septic interpretation, it can provide preliminary septic interpretations of GNF soils within the Gallatin LWQD. Methodologies used in this study may be transferable to other areas of the Rocky Mountain West susceptible to rural expansion.

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APPROVAL

of a thesis submitted by

William Thomas Christner Jr.

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Cliff Montagne ____Cliff Montagne____ 8/19/99
Date

Approved for the Department of Land Resources and Environmental Sciences

Jeffrey S. Jacobsen ____Jeffrey S. Jacobsen____ 8/18/99
Date

Approved for the College of Graduate Studies

Bruce R. McLeod ____Bruce R. McLeod____ 8-19-99
Date

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Date August 19, 1999

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ABSTRACT

Demographic changes throughout the Rocky Mountain west are resulting in an increasing number of rural subdivisions away from city centers. Rural housing developments require on-site sewage disposal systems to handle household waste. Development of large tracts of formerly range and forest soils, has produced the need for septic system suitability information of these soils. Range and forest soils, typically covered by third order soil surveys, are not intended for septic interpretations. However, they may contain the data necessary for septic interpretations. The Gallatin Local Water Quality District (LWQD) in southwestern Montana contains portions of Gallatin Valley and Gallatin National Forest (GNF) soils within its boundaries. Gallatin Valley soils are lowland agricultural soils covered by a second order soil survey and have been interpreted for on-site sewage disposal systems. GNF soils are higher elevation range and forest soils covered by a third order soil survey and are not interpreted for on-site sewage disposal systems. The Gallatin LWQD provides the opportunity to determine if the third order GNF soil survey contains the data necessary for septic system interpretations. This case study also provides the opportunity to compare septic interpretations from second order Gallatin Valley soils to septic interpretations from corresponding third order GNF soils along the Gallatin Valley/GNF border.

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Complete septic interpretations (slight, moderate and severe) for all restrictions were compared between corresponding Gallatin Valley/GNF border map units. Results showed a high percent match (73%) between the complete septic interpretation of corresponding Gallatin Valley/GNF border map units. These results were consistent in a refined comparison that weighted each GNF map unit according to its percent match with its corresponding Gallatin Valley map unit. This method produced a 75 percent match.

Septic interpretations based on observations from twenty-four field soil pits suggested that restrictions with high percent match results were favored by a high number of map units with "slight" limitations. Comparisons based on a broad range of limitation data (slight, moderate and severe) showed higher agreement with GNF data than Gallatin Valley data ($p = 0.74$ vs. 0.65 respectively).

I found that although the third order GNF soil survey was not designed for septic interpretation, it can provide preliminary septic interpretations of GNF soils within the Gallatin LWQD. Methodologies used in this study may be transferrable to other areas of the Rocky Mountain West susceptible to rural expansion.

CHAPTER 1

INTRODUCTION

Demographic changes throughout the rocky mountain west are resulting in an increasing number of rural subdivisions away from city centers. Similar changes in Gallatin County have produced a shift from an economy based on agriculture and forestry to one based on recreation and land development. According to the Montana Agricultural Statistics Service, the amount of agricultural land in the state has been declining since 1978. In 1969 nearly sixty percent of Gallatin County was in agriculture. By 1992 the figure had dropped to forty-four percent (Schontzler, 1996). The loss of agricultural land has been accompanied by an increase in the population of the Gallatin Valley and in the number of rural properties subdivided. Rural housing developments in Gallatin Valley require on-site septic systems to handle household waste disposal. Rural housing developments without proper planning and site selection can threaten and, in some cases, contaminate surface and ground water resources through septic system failure (Bauder, 1993). Proper septic system location and design requires knowledge of the soil properties that affect the construction and function of septic systems (Soil Survey Staff, 1993; Montana Department of Health and Environmental Sciences, 1992). This knowledge will minimize the potential for pollution and health hazards in local and regional areas and also help minimize construction costs (Bauder, 1993; Montana Water Quality Bureau Circular WQB 6, 1992; Tinker, 1990). Soil information regarding septic system limitations can aid system design and installation and also reduce the risks to surface and ground water resources. The availability of the soil information necessary to determine the septic system limitations of an area depends on the type of soil survey conducted for the area.

There are five different levels of soil survey described by the Soil Survey Staff of the United States Department of Agriculture (Soil Survey Staff, 1993). Each level of soil survey reflects a change in scale, level of detail and uses for which the soils can be interpreted. The lower the order the more intensive and, therefore, the more detailed the soil survey.

First order soil surveys are very intensive and detailed surveys performed on small areas. Surveys of this order are used to obtain precise information for site specific planning objectives such as irrigation, drainage, specialty crops and building sites. They provide detailed information on the soils and their variability. Base map scale is 1:15,840 or larger. Second order soil surveys are intensive and detailed surveys performed on larger areas. They are more inclusive, rather than site specific, soil surveys used to plan agriculture, construction and urban development where detailed information about soils and their variability are required to assess treatment needs and suitable uses. Map scales range from 1:12,000 to 1:31,680. Third order soil surveys are extensive surveys for large areas that require less detail or precise soil information. They are typically used to identify a single land use with few subordinate uses. This level of survey is used to assist in general range, forest, recreational and community planning. Map scales range from 1:20,000 to 1:63,360. Fourth order soil surveys are extensive surveys of large areas that require more generalized soil information. They are used in regional land use planning and to select areas which require more intensive study and/or investigations. They provide broad information concerning land use potential and general land management. Map scales range from 1:63,360 to 1:250,000. Fifth order soil surveys are very extensive surveys for large areas that require very generalized soil information. They are used for planning regional land use and interpreting very generalized information and to select areas for more intensive study and/or investigation. Map scales range from 1:250,000 to 1:1,000,000.

Soil survey interpretations are keyed to a particular land use, which evolve over time and periodically require revision. When the intended use of the soils covered by a specific survey changes, additional information may be needed to interpret a soil for the new use. This requires re-evaluation of the initial soil survey, and may establish the need for a new, more detailed soil survey of the area. Alternatively, the initial survey may contain the necessary data to make the new interpretation. As rural subdivisions move further away from city centers, significant portions of range and forest soils are subdivided. Range and forest soils are generally covered by third order soil surveys which are not intended for septic system interpretations. However, the data necessary to assess septic system limitations may exist in a third order soil survey. If the data do exist, it would save the time and money required to perform a new, more detailed soil survey, providing a valuable database to facilitate rural subdivision planning. The

Gallatin Local Water Quality District (LWQD) is in need of this type of information.

The Gallatin LWQD, located in Gallatin County, Montana (Figure 1), was created in 1997 to take responsibility for the quality of the water resources within its boundaries. It encompasses land in both Gallatin Valley and the Bridger, Bangtail, and Hyalite mountains of Gallatin National Forest (GNF). At the time of its creation, Gallatin County health officials identified the need for a data base which would provide the necessary information to assess septic system location, construction and operation within the Gallatin LWQD. The second order soil survey of the Gallatin County Area[1], which covers Gallatin Valley soils, has been interpreted for septic system limitations however, the third order GNF soil survey has not. This poses a problem for the Gallatin LWQD.

Many areas of the GNF within the Gallatin LWQD contain alternate one-square mile sections in private ownership. This "checkerboard" ownership dates back to the early settlement of the West when the Federal Government granted every other section bordering a railroad corridor to the railroad companies. Today private individuals and companies own these sections. Occasionally the private owner will offer to "swap" these checkerboard sections with the Forest Service for an equal value of continuous sections in another area. Through this method, recently privatized land may become available for housing development after the timber has been harvested. When development occurs, information regarding the septic system limitations of GNF soils will be needed to help

1

Because the second order soil survey of Gallatin County Area includes only the soils in Gallatin Valley and not GNF, it is hereby referred to as the second order soil survey of Gallatin Valley.

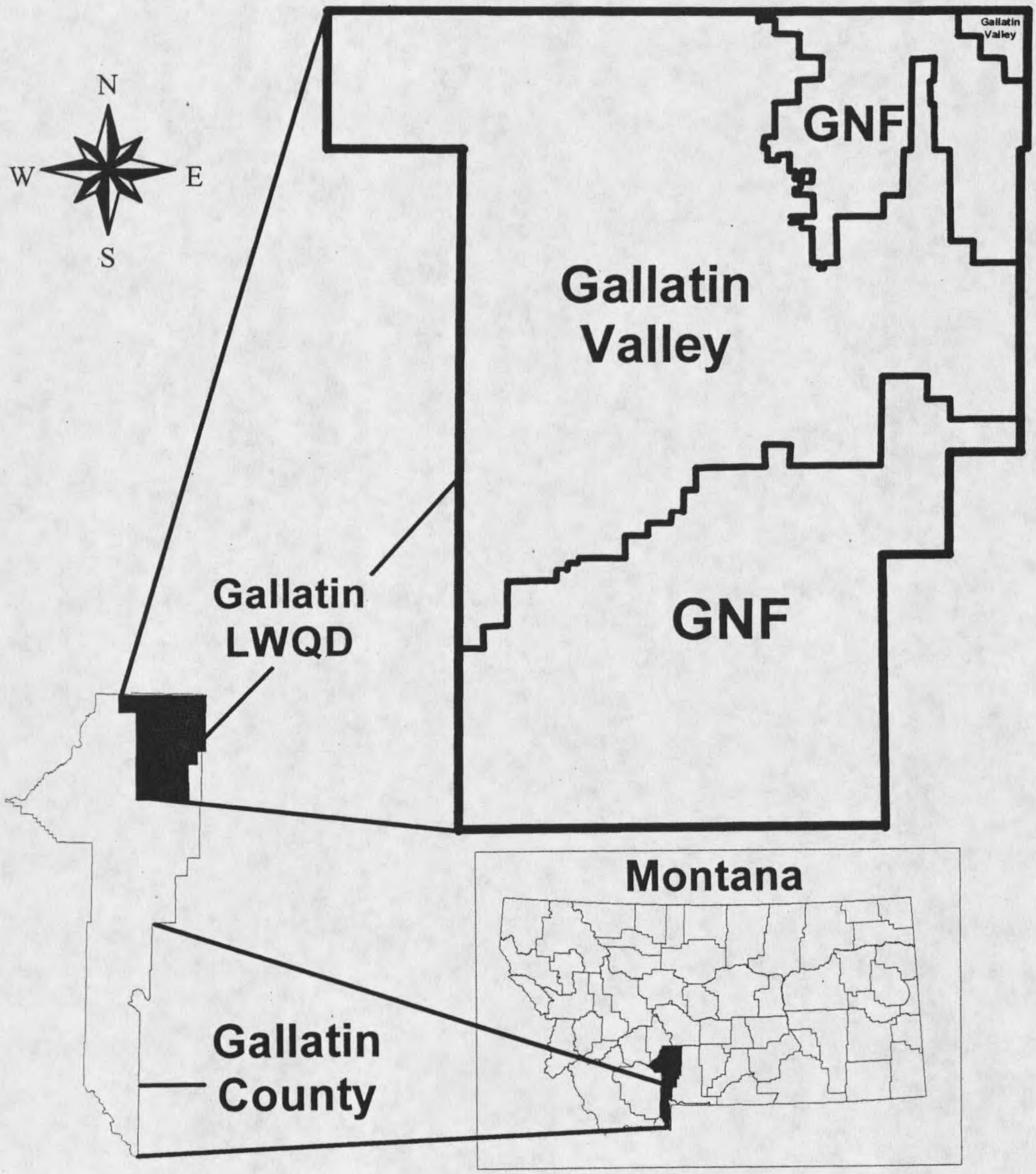

Figure 1. Location of Gallatin LWQD within Gallatin County, Montana. Gallatin LWQD contains portions of Gallatin Valley and GNF within its boundaries.

insure proper planning of septic system location, construction and operation. Since housing development is not one of the management objectives for GNF, the GNF soil survey was not interpreted for septic system limitations. However, the possible development of GNF land indicates a need for such interpretations. Although the third order GNF soil survey was not designed for septic system interpretations, the survey may contain sufficient data to assess the septic system limitations of the soils. This information would help the Gallatin LWQD attain its goals and also provide Gallatin County health officials with a valuable database. The GNF soil survey was evaluated to ascertain if adequate soil data exists to produce preliminary septic interpretations of GNF soils. The Gallatin LWQD provided the opportunity to determine if septic system interpretations can be obtained from a third order soil survey and, through comparison with the septic system interpretations from the second order Gallatin Valley soil survey, the opportunity to investigate the reliability of the third order survey interpretations. This case study provides perspective for other areas with similar trends and needs in southwestern Montana and other western regions where urban sprawl has the potential to extend from city centers into range and forest areas with checkerboard ownership.

CHAPTER 2

ASSESSING SEPTIC SYSTEM LIMITATION PARAMETERS FROM A THIRD ORDER SOIL SURVEY

Introduction

Assessing septic system limitations requires specific information concerning ten soil properties (Table 1). These properties are: USDA soil texture, frequency and duration of flooding, depth to bedrock, depth to cemented pan, frequency and duration of ponding, depth to high water table, permeability between sixty and one-hundred and fifty centimeters, percent slope, percent coarse fragments by weight, averaged to a depth of one meter and, total subsidence potential (Soil Survey Staff, 1993). Limitations are described in terms of severity; "slight", "moderate" and "severe." "Slight" limitations present minor problems for septic installation and/or operation.. "Moderate" limitations do not require exceptional risk or cost but the soil does possess certain undesirable properties or features. "Severe" limitations require unacceptable risk to use the soil if not appreciably modified. Special design will significantly increase construction costs and appreciably higher maintenance cost is required for satisfactory performance of the

Table 1. Soil properties, limitations and, restrictive features for septic tank adsorption fields (after Table 620-17, National Soil Survey Staff, 1996).

Property	Limitations: Slight	Limitations: Moderate	Limitations: Severe	Restrictive Feature	Installation (I) and/or Effluent (E)
USDA Texture	—	—	Ice	Permafrost	I
Subsidence (cm)	—	—	> 60	Subsides	I
Flooding	None	Rare	Frequent/ Occasional	Flooding	E
Depth to Bedrock (m)	> 1.8	1.0 - 1.8	< 1.0	Depth to Rock	E/I
Depth to Cemented Pan (m)	> 1.8	1.0 - 1.8	< 1.0	Cemented Pan	E/I
Ponding	(-)	(-)	(+)	Ponding	E
Depth to High Water Table (m)	> 1.8	1.2 - 1.8	< 1.2	Wetness	E
Low Permeability (0.6- 1.5 m, cm/hr)	5.0 - 15.0	1.5 - 5.0	< 1.5	Slow Perc	E
High Permeability (0.6- 1.5 m, cm/hr)	5.0 - 15.0	1.5 - 5.0	> 15.0	Poor Filter	E
Percent Slope	< 8	8 - 15	> 15	Slope	I
Large Stones > 76 mm (weighted avg. to 1 m)	< 25	25 - 50	> 50	Large Stones	I

septic system. Soil data used to determine septic system limitations can be grouped into two categories: those that affect the absorption of the effluent and those that interfere with the installation of the system (Soil Survey Staff, 1993; Montana Water Quality Bureau Circular WQB 6, 1992).

Soil properties that affect effluent absorption are flooding, bedrock, cemented pan, ponding, high water table, and permeability. Soil permeability rates indicate the amount of time septic effluent interacts with the soil. High permeability rates do not allow soil enough time to adequately filter septic effluent. Slow permeability rates may result in septic effluent bypassing the adsorption field and/or accumulating at or near the soil surface. High water tables and flooding cause saturation of the absorption field and reduce septic effluent filtering. Shallow bedrock and cemented pans reduce the total thickness of an adsorption field, therefore reducing its capacity to filter septic effluent (Soil Survey Staff, 1993).

Septic system installation is also a concern. Soil properties that affect septic system installation include soil texture, subsidence, bedrock, cemented pan, slope and coarse fragments. Shallow bedrock, cemented pan, the presence of ice, stones and boulders all interfere with excavation. Stones and boulders may damage a system during backfill operations. Subsidence interferes with septic system installation and maintenance (Soil Survey Staff, 1993). Information regarding these soil properties is required to assess the septic system limitations of GNF soils.

Data regarding soil properties that effect septic system installation and operation may exist in the third order GNF soil survey. However, because of the greater level of generalization in a third order soil survey, the reliability of the data is unknown. Since the GNF soil survey has not been interpreted for septic system limitations, and certain portions of the GNF that lie within the Gallatin LWQD are subject to development, it is necessary to determine if the information available in the third order GNF soil survey can provide reliable septic interpretations for GNF soils. The research objective is to determine if the protocol used to interpret the second order Gallatin Valley soil survey for septic system limitations may be used to establish the septic system limitations for the third order GNF soil survey, using the data available in the third order GNF soil survey.

Study Area

The study area is located in the Rocky Mountain region of southwestern Montana. The study site consists of Gallatin Valley and GNF soils within the Gallatin LWQD (Figure 1). Gallatin Valley soils are low elevation soils dominated by the accumulation of surface deposits (alluvium and loess). They are used primarily for home sites, recreation, and agriculture. GNF soils are high elevation range and forest soils located in the mountain around Gallatin Valley. They occur in landforms dominated more by bedrock and, to a lesser extent, alluvium and glacial till. They are used primarily for recreation, wildlife habitat, and timber production.

Purpose

The purpose of this part of the study is to determine if the third order GNF soil survey contains the data necessary to calculate septic system interpretations. If the data do exist, each GNF map unit will be interpreted for septic system limitations. An ArcView™ coverage based on the most limiting septic interpretation will be constructed for the GNF soils within the Gallatin LWQD. Finally, consistency of the septic system interpretation for GNF soils will be examined along the border between second order Gallatin Valley soils and third order GNF soils.

Methods

Locating the Data and Determining the Limitation

Soil data necessary to establish septic system limitations was obtained from the Soil Survey of Gallatin National Forest, Montana final report, July 1996, and the interim draft report, April 1984 (Table 2). The final report contains data on flooding potential, ponding potential, depth to high water table, permeability, percent slope and percent coarse fragments. The interim draft report contains data on depth to bedrock. The reports contain information regarding depth to cemented pan and USDA soil texture. However, cemented pans and permafrost (the only restriction for soil texture) do not occur in this region, therefore the information is not required. Information on subsidence potential does not exist for GNF soils. Subsidence potential is the potential decrease in surface elevation as a result of drainage of wet soils having organic layers or semifluid mineral layers (Soil Survey Staff, 1993). According to the soil survey leaders for Gallatin Valley and GNF, soils exhibiting this potential do not exist in the Gallatin LWQD or, exist in an areal extent smaller than the map unit scale of either soil survey (personal communication 1998; Rolfes, Resource Soil Scientist, USDA-NRCS Bozeman, MT; Shovic, Soil Scientist, USFS Interagency Spatial Analysis Center-Gallatin National Forest, Bozeman, MT).

Table 2. Source of septic system limitation information for GNF soils, (Davis and Shovic, 1984 and 1996.

Property	Source
Flooding potential	Taxonomic classification, Table 13, GNF final report Landform, Table 1, GNF final report
Depth to bedrock (in)	Table 1, GNF interim draft report
Ponding potential	Table 6, GNF final report
Depth to high water table (in)	Representative pedon description, GNF final report
Permeability, 24" - 60" (in/hr)	Representative pedon description, GNF final report
Percent slope	Table 1, GNF final report
Percent coarse fragments	Representative pedon description, GNF final report

Flooding potential information was obtained by interpreting Tables 1 and 13 in the GNF soil survey final report. Table 1 of the GNF soil survey final report provides landform information for each soil map unit. Landforms are defined by slope, shape of slope, pattern and density of low order streams, relief and other properties (Davis and Shovic, 1996). Landforms associated with flooding are stream terraces and floodplains.

Table 13 of the GNF soil survey final report lists the family, or higher, taxonomic classification of each soil within the map unit. Taxonomic classifications contain formative elements that indicate proximity to a floodplain. The formative element associated with floodplain deposits on which soils develop is *fluv*, derived from the Latin *fluvius* for river. The connotation of *fluv* is a floodplain. After the flooding potential of a map unit is determined a limitation is assigned.

Limitations are assigned based on flooding characterization of the soils and the corresponding flood frequency over a one hundred year period (Table 3). A slight limitation is assigned when there is no reasonable possibility of flooding (none). A moderate limitation is assigned when the flooding frequency is between zero to five times in one hundred years (rare). A severe limitation is assigned when the flooding frequency is greater than five times in one hundred years (occasional/frequent), (Soil Survey Staff, 1993). Flood frequency is determined by landscape position, soil morphology/stratification and, floodplain maps (personal communication 1998; Tony Rolfes, Resource Soil Scientist, USDA-NRCS Bozeman, MT). If available floodplain maps take precedence.

No floodplain maps exist for the GNF. Therefore, existing information on landform position and soil morphology/stratification from the GNF soil survey were used to determine the flooding frequency for each GNF map unit. Previous studies have documented the use of soil surveys to delineate areas subject to flooding (Cain and Beatty, 1968; McCormick, 1971). Three GNF map units within the Gallatin LWQD are described as having the potential to flood; 64-2A, 64-2C and 66-1A. Landforms in map

Table 3. Flood frequency criteria and classification used to determine septic system limitations for flooding, (after Table 3-4, Soil Survey Manual, 1993).

Classification	Frequency Criteria
None (N)	no reasonable possibility
Rare (R)	1 -5 times in 100 years
Occasional (O)	5 - 50 times in 100 years
Frequent (F)	≥ 50 times in 100 years
Common (C)	occasional and frequent can be grouped for certain purposes called common

units 64-2A and 64-2C consist of glacial outwash benches and terraces, floodplains and terraces. These soils are subject to flooding after prolonged, high intensity storms (Davis and Shovic, 1984). Landforms in map unit 66-1A consist of floodplains. These soils are frequently flooded (Davis and Shovic, 1984). Map units 66-2A and 66-2C were classified as flooding occasionally (5 - 50 times in 100 years). Map unit 66-1A was classified as flooding frequently (≥ 50 times in 100 years). All three map units received a "severe" septic system limitation for flooding based on their flooding classification.

Depth to bedrock information was obtained from Table 1 of the GNF soil survey interim draft report. Table 1 lists a depth to bedrock range for each map unit based on field observations (Davis and Shovic, 1984). The most limiting value in the range was used to calculate the septic system limitation. A "slight" limitation was assigned when depth to bedrock was greater than 1.8 meters. A "moderate" limitation was assigned when depth to a bedrock was between 1.0 to 1.8 meters. A "severe" limitation was assigned when depth to bedrock was less than 1.0 meters (Soil Survey Staff, 1993).

Ponding potential information was obtained from Tables 6 and 13 of the GNF soil survey final report. Table 6 of the GNF soil survey final report lists the frequency of wet areas as low, moderate or high for each map unit. A low rating indicates that wet areas occur infrequently and are easily avoided. A moderate rating indicates that wet areas occur commonly but can normally be avoided. A high rating indicates that wet areas are difficult to avoid entirely (Davis and Shovic, 1984). Ponding information may also be obtained from the taxonomic classification of a soil.

Formative elements associated with water in the soil are *aqu* and *hydr*. *Aqu* is derived from the Latin *aqua* which means water and connotes a characteristic associated with wetness. *Hydr* is derived from the Greek *hydro*, meaning water and connotes the presence of water , (Soil Survey Staff, 1998). Ponding limitations are determined by a binary , +/-, process. The soil either ponds or it does not. A positive value results in a "severe" septic system limitation (Soil Survey Staff, 1993). A "severe" limitation was assigned to GNF soils based on two criteria. First, the map unit must have a "high" frequency of wet areas in Table 6 of the GNF soil survey final report and second, the map unit taxonomic classification must indicate wetness.

Depth to high water table information was obtained from the representative pedon description in the GNF soil survey final report. The limitation is based on the presence of free water in the soil profile. This is accomplished through direct contact with the water table or is inferred through the presence or absence of redoximorphic features in the soil profile. Redoximorphic features, such as mottles and gleying, are soil properties associated with wetness and result from the oxidation of iron and manganese compounds in the soil after saturation with water and subsequent drainage (Roth et. al, 1997). Previous studies have documented the use of redoximorphic features to infer water table depth and soil drainage (Simonson and Boersma, 1972; Vepraskas and others, 1974; Bouma, 1983; Franzmeier and others, 1983; Vepraskas and Wilding, 1983; Pickering and Veneman, 1984; Watts and Hurt, 1991; Vepraskas, 1996). The presence of redoximorphic features in the representative pedon description was used to infer water table depth. A "slight" limitation was assigned where the water table was greater than 1.8 meters below the soil surface. A "moderate" limitation was assigned when the water table was between 1.2 to 1.8 meters below the soil surface and a "severe" limitation was assigned when the water table was less than 1.2 meters below the soil surface (Soil Survey Staff, 1993).

Permeability class for each map unit was determined through the application of the USDA-NRCS field guide for determining relative permeability (Table 4). Permeability classes are based on a combination of soil texture and structure. Corresponding permeability values were assigned according to Part 618.44b of the USDA National Soil Survey Handbook (Table 5). Acceptable permeability values range from 1.5 (cm/hr) to 15.0 (cm/hr). A "slight" limitation was assigned when permeability was between 5.0 - 15.0 (cm/hr). A "moderate" limitation was assigned when permeability was greater than or equal to 1.5 (cm/hr) and less than 5.0 (cm/hr). A "severe" limitation was assigned when permeability was greater than 15.0 (cm/hr) or less than 1.5 (cm/hr) (Soil Survey Staff, 1993). Permeability values greater than 15.0 and less than 1.5 (cm/hr) both produce "severe" septic system limitations.

Information on percent slope for each map unit was obtained from Table 1 GNF Soil Survey final report which lists a slope range for each map unit. The highest, or most limiting, value in the range, was selected to determine slope limitations. A "slight" limitation was assigned to slopes less than eight percent. A "moderate" limitation was assigned to slopes between eight and fifteen percent. A "severe" limitation was assigned to slopes greater than fifteen percent (Soil Survey Staff, 1993).

Information on the presence and amount of coarse fragments was obtained from the representative pedon description in the GNF Soil Survey final report. The value is a weighted average to a 100 centimeter depth. The contribution of each horizon was calculated with equation 1:

Eq 1. [percent coarse fragments in horizon] x [horizon thickness (cm)/100 (cm)]

Values for each horizon to a 100 centimeter depth were summed to produce the value used to determine the septic system limitation for large stones. A "slight" limitation was assigned to values less than twenty-five percent. A "moderate" limitation was assigned to values between twenty-five and fifty percent. A "severe" limitation was assigned to values greater than fifty percent.

Table 4. Field guide for determining relative permeability class based on a combination of soil texture and structure, (after Exhibit 618-9, National Soil Survey Handbook , Soil Survey Staff, 1996).

	Soil Structure		
Texture	Massive or Platy	Blocky or Prismatic	Single Grain or Weak Prismatic
c, sic, sc	Very Slow	Slow	
cl, sicl, scl, sil, l	Slow	Moderately Slow to Moderate	
sl, fl, vfsl		Moderately Slow to Moderate	Moderately Rapid, Rapid, Very Rapid
ls, s, lcs, cls			Moderately Rapid, Rapid, Very Rapid

Table 5. Permeability values assigned to corresponding permeability classes, (After section 618.44b, National Soil Survey Handbook, Soil Survey Staff, 1996).

Permeability Class	Permeability Value (cm/hr)
Very Rapid	51 - 254
Rapid	15 - 51
Moderately Rapid	5 - 15
Moderate	2 - 5
Moderately Slow	0.5 - 1.5
Slow	0.15 - 0.5
Very Slow	0.0038 - 0.15
Impermeable	0.00 - 0.0038

Calculating the Septic System Limitation

To reduce the chance for error in determining the septic system limitation for each of the ninety-four GNF soil map units, a logic-based program was constructed within Quattro Pro 5.0™ spreadsheet to calculate the septic system limitation for each map unit. The program consists of a series of nested, logical, if/then functions. Figure 2 shows the spreadsheet results for map unit 12-1A. As entries were made in the "Value" column the logical functions determined the corresponding septic system limitation, "slight", "moderate" or "severe", for each of the nine soil properties. The program then determined the most limiting restriction for the map unit and assigned a color to each map unit corresponding to the septic system limitation for that restriction. Restrictions range from most to least limiting in the following order: flooding, bedrock, ponding/wetness, slow perc, poor filter, slope and large stones. Map units possessing multiple "severe" restrictions have the most limiting restriction assigned to the map unit. The assigned color was used to construct a septic system limitation coverage with an ArcView™ software program.

Equations 2 and 3 illustrate how the program works. Cell C4 contains equation 2 which determines the septic system limitation for flooding.

Eq. 2. @IF(B4="none","slight",@IF(B4="rare","moderate","severe"))

In plain words this equation states, " if cell B4 contains the word "none", put the word "slight" in cell C4; if not then if cell B4 contains the word "rare" put the word "moderate" in cell C4, if not then put the word "severe" in cell C4."

	A	B	C	D
1	Map Unit: 12-1A	Map Unit Limitation: severe		
2	Dystic Cryocrepts, loamy-skeletal, mixed.	Map Unit Color: brown w/diagonal lines Most Limiting Restriction: slow perc		
3	Property	Value	Limitation	Restrictive Feature
4	Flooding	none	slight	
5	Depth to bedrock (cm)	121.9	moderate	
6	Depth to cemented pan (cm)	>186	slight	
7	Ponding	-	none	
8	Depth to water table (cm)	>186	slight	
9	Permeability (cm/hr)	0.15	severe	slow perc
10	Percent Slope	20	severe	slope
11	Percent Coarse Fragments	50.5	severe	large stones
12	Subsidence	0.0	none	

Figure 2. Example of computer generated septic system interpretation for GNF map unit 12-1A. Note that restrictive features are listed only when the soil property rates "severe".

Cell D4 contains equation 3. The output displays the restrictive feature for severe flooding limitations.

Eq. 3. @IF(C4="severe","Flooding"," ")

In plain words this equation states, "if cell C4 contains the word "severe", put the word "flooding" in cell D4; if not leave cell D4 blank.." Similar equations were written for the other cells in the program to determine the proper septic system suitability limitation and the appropriate color assigned to each map unit. Septic system interpretations for all GNF soil map units were calculated (Appendix A) based on data from the GNF soil survey (Appendix B). Results were compiled in a spreadsheet file and combined with the GNF ArcView™ attribute file for the GNF soil coverage. Finally, an ArcView™ coverage, based on the most limiting septic system restriction, was created for GNF soils.

ArcView™ is a map display and query software program that can read Arc/Info™ coverages (maps) without modification and permits projection of spatially distributed data. It allows data to be examined and/or manipulated to answer questions and solve problems, and also provides printed maps and graphics according to user specifications (Baker, 1999). ArcView™ attribute information can be linked to map coverages. Map coverages can be classified and limitations assigned based on specific attribute values. Figure 3 is an example of an ArcView™ coverage illustrating the current septic system interpretations for Gallatin LWQD. The coverage shows the "most-limiting" restriction of each Gallatin Valley soil map unit for on-site sewage disposal systems. This coverage was developed by interpreting the 1998 USDA-NRCS soil survey of the Gallatin County Area, Montana (Rolfes et. al, 1998).

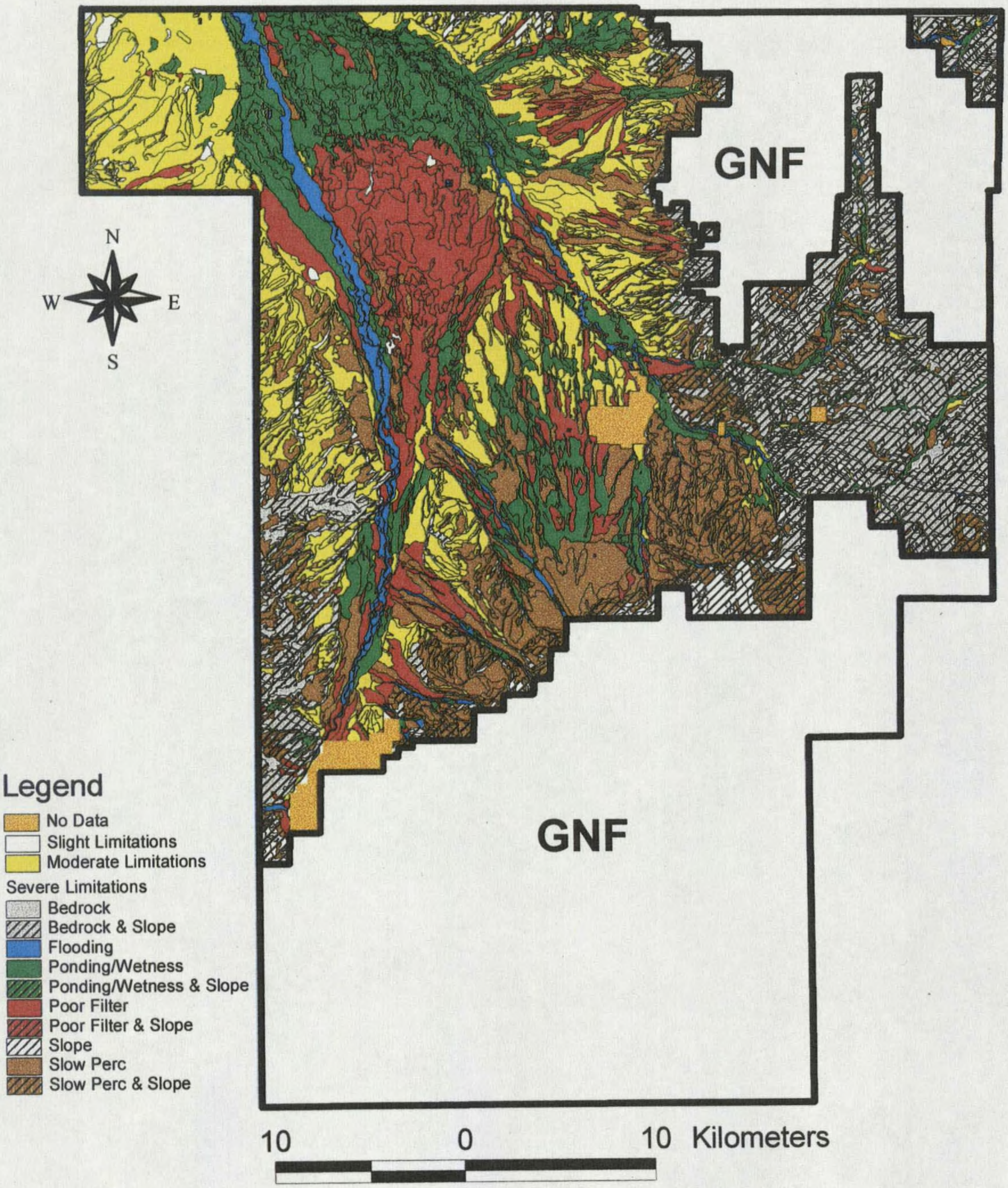

Figure 3. ArcView™ coverage illustrating the most limiting septic system restriction for Gallatin Valley soils within Gallatin LWQD, Montana (after Rolfes et. al, 1998).

Results and Discussion

The third order GNF soil survey contains the information required to determine septic system limitations within the Gallatin LWQD. Figure 4 shows the ArcView™ coverage of the most limiting septic system restriction for each GNF soil map unit within the Gallatin LWQD. All ninety-four GNF map units possess "severe" septic system limitations. Of these, seventy-six are represented in the Gallatin LWQD (Figure 5). Shallow soils over bedrock and slow percolation rates account for the majority of the restrictions. Thirty-three GNF map units possess "severe" limitations for bedrock and thirty-two possess "severe" limitations because of slow percolation rates. The remaining eleven map units possess "severe" limitations for fast percolation rates (5), ponding/wetness (3), and flooding (3). Additionally, all GNF map units possess multiple "severe" limitations ranging from two to five restrictions (Appendix A). Visual observation of the septic system limitation coverage shows the limitations agree with known field conditions. Soils located on valley bottoms along stream channels have flooding restrictions while soils located on structurally controlled slopes and ridges have bedrock restrictions.

GNF soils make-up two areas within the Gallatin LWQD, one in the northeast the other in the south. The northeast section of the LWQD is comprised of the Bridger and Bangtail mountains. Map units in this area are dominated by soils with bedrock (grey areas) and slow percolation (brown areas) restrictions.

Bedrock geology of the Bangtail mountains consists of sedimentary units of the Livingston Group. Soils are underlain by hard, ridge-forming sandstones and

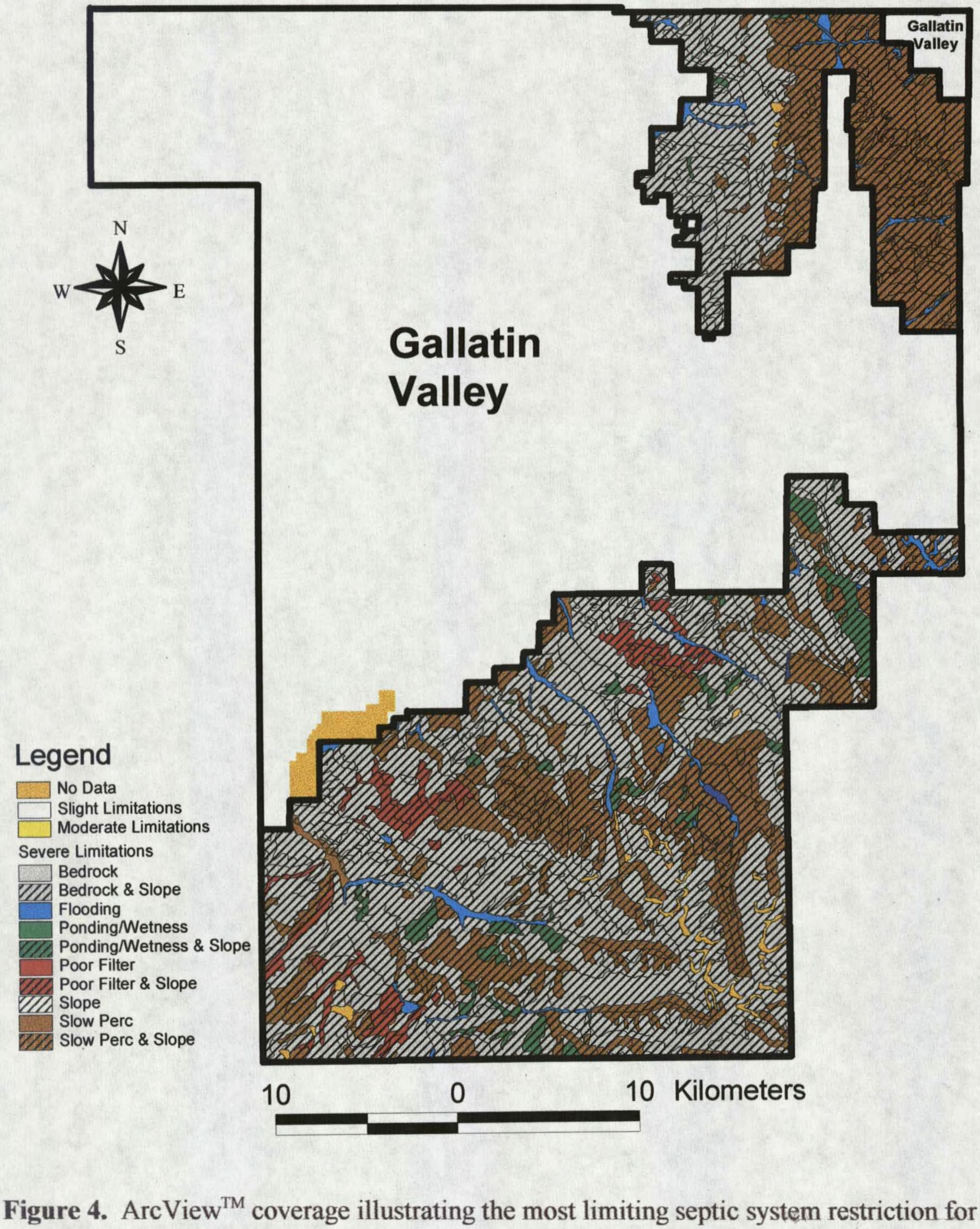

Figure 4. ArcView™ coverage illustrating the most limiting septic system restriction for GNF soils within Gallatin LWQD, Montana.

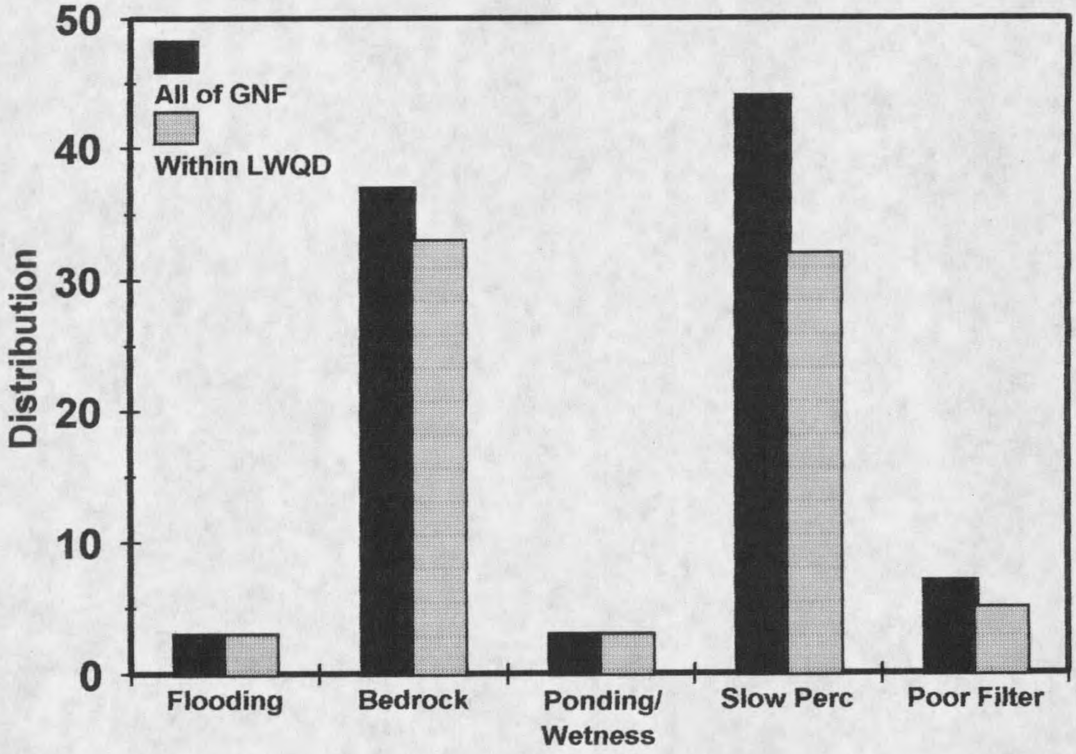

Figure 5. Distribution of the most limiting septic system limitation for individual GNF map units within 1) GNF boundaries and, 2) Gallatin LWQD boundaries.

conglomerates, and soft, swale-forming, fine-grained siltstone, mudstone, and shales (Veseth and Montagne, 1980). Hard, resistant residual parent materials, like sandstone and conglomerate, tend to form thin soils due to slower weathering rates and increased slopes. Colluvial sandstone and conglomerate parent materials form deeper, coarse textured, highly leached, and permeable soils. These soils generally have high percolation restrictions (poor filter) and a "severe" septic limitation signified by red on the limitation coverage. Soils derived from fine grained siltstone, mudstone and/or shale tend to be clayey, somewhat impermeable, little leached, and shallow (Buol and others, 1997). Map units with these soils have slow percolation restrictions (slow perc) and a "severe" septic limitation signified by brown in the limitation coverage.

Bedrock geology of the Bridger mountains within Gallatin LWQD consists of Proterozoic sedimentary and metasedimentary rocks, Archean metamorphic gneiss, Paleozoic carbonates and shales, and Mesozoic sandstones and shales (Locke and Lageson, 1989). Ridge-forming units are composed of the massive, Mississippian age, Mission Canyon and Lodgepole limestones (Veseth and Montagne, 1980). Soils in this section of the Bridger mountains are developed from colluvial and residual parent material derived from these rock types. Soil depth varies with landscape position (concave versus convex slopes) from 0.10 meter to more than 1.5 meters (Davis and Shovic, 1996). Thin soils are shallow to bedrock, signified by grey in the limitation coverage. Deeper soils are coarse grained, calcareous and permeable. Map units with these soils have high percolation restrictions (poor filter) and a "severe" septic limitation signified by red on the limitation coverage.

GNF soils in the southern section of the LWQD are dominated by bedrock, slow percolation, and to a lesser extent, fast percolation, ponding/wetness, and flooding restrictions. Septic restrictions coincide with landscape position, depth to bedrock, and parent material composition. Bedrock geology varies throughout this area. Archean high-grade metamorphic rock, Paleozoic, Mesozoic and Cenozoic sedimentary units are found at various locations throughout the northern part of the region. Tertiary volcanics of Cenozoic age cap these rocks in the southern part. Portions of this area have also been glaciated. Glacial processes have formed cirques, peaks and ridges at higher elevations. These geologic processes and various geologic units provide a range in the mineral composition of the parent materials from which the soils are formed. This is reflected in the contrasting septic system restrictions for the area.

Soils with a slow percolation restrictions (brown) are developed from residual and colluvial parent materials of sedimentary and volcanic composition. Sedimentary rocks include shale, mudstone, siltstone and sandstone. Volcanic rocks are dominantly andesitic in composition. Soils derived from volcanic parent material develop into noncalcareous loamy to silt and clay loam soils. These soils are moderately permeable and contain a moderate to high percentage of coarse fragments (Veseth and Montagne, 1980). Soils developed from the fine grained sedimentary rocks contain a moderate amount of clay, are moderately permeable, and contain a low to moderate amount of coarse fragments (Davis and Shovic, 1996). Map units with these soils have slow percolation restrictions (slow perc) and a "severe" septic limitation signified by brown on the limitation coverage. Soils with a ponding/wetness restriction are developed from similar parent materials but the limitation is governed by the topography in the map unit.

Three GNF map units in the southern section of the Gallatin LWQD have a "severe" ponding/wetness limitation (green) for septic systems. Landslides have produced a hummocky landform in these map units with mounds and depressions. Ponds and bogs are present in the depressions (Davis and Shovic, 1996). Soils in these map units have slow percolation rates and, together with depressional topography, result in a "severe" limitation for septic systems signified by green on the limitation coverage.

Flooding potential is also determined by the landforms in a map unit. Flooding is the least common restriction because waterways comprise a small percentage of the land area. Two GNF map units possess “severe” flooding limitations for septic systems. Landforms in these map units are described as terraces and floodplains. Due to their proximity to waterways, these soils are subject to flooding after sustained precipitation events (Davis and Shovic, 1986). Soils in these map units possess a “severe” flooding limitation for septic systems signified by light blue on the limitation coverage. The majority of GNF soils located above the floodplain possess a “severe” bedrock limitation (grey) for septic systems.

GNF soils with bedrock less than 1.8 meters from the soil surface have a “severe” bedrock restriction for septic systems. Hard, resistant igneous, sedimentary and metamorphic rocks produce complex landforms. These map units contain between twenty to eighty percent exposed bedrock with thin soils formed from colluvial and residual parent materials on steep, structurally controlled slopes (Davis and Shovic, 1984). Soils in these map units possess a “severe” limitation for septic systems signified by grey on the septic limitation coverage.

CHAPTER 3

ASSESSING THE VALIDITY OF THE GNF SEPTIC SYSTEM INTERPRETATION

Introduction

Interpretation of a soil for septic system limitations does not imply any level of confidence in the assigned limitations. Potential users of the data should be aware of the accuracy before any landuse and/or planning decisions are based on the data. Potential users of this database include perspective homeowners, county sanitation personnel, private consultants, engineers, and GNF personnel.

Perspective homeowners can use this data to ascertain what soil problems they may encounter on their property regarding on-site sewage disposal. Department of Environmental Health personnel can use the data to provide preliminary information to perspective homeowners and/or developers regarding the septic limitation of soils. Private consultants and engineers can use the data to provide preliminary estimates to clients regarding septic system cost, design, and modification based on septic limitations. Forest Service personnel can use the data to evaluate the suitability of lands for subdivision and potential land value . Additionally, the data base may help planners, owners and developers recognize, and justify, the need for a more detailed soil survey of a particular area. Information regarding the validity of the data needs to be ascertained so users of the information may be aware of the level of accuracy and suitability of the data for landuse and/or planning purposes. The border between Gallatin Valley and GNF provides an opportunity to investigate the accuracy of the GNF data.

The border between Gallatin Valley and GNF represents an artificial, man-made, boundary. Soil properties should not change abruptly across the boundary from Gallatin Valley into GNF therefore, the septic system restriction assigned to these border map units should be the same. Since the septic system restriction is not expected to change across an artificial boundary, there should be a high percent match between septic interpretations of corresponding Gallatin Valley/GNF border map units. A complicating factor is that the Gallatin Valley/GNF border roughly parallels an ecological transition zone between the lower elevation Gallatin Valley and the higher elevation and steeper sloping soils of GNF. This transition is marked by changes in four soil forming factors: climate, biota, topography and parent material. Therefore, GNF soils will have: 1) higher annual precipitation and lower mean annual temperatures, 2) different fauna/flora, 3) increases in slope complexity and, 4) more bedrock dominated landforms. Changes to these four soil forming factors can produce changes in the type of soil formed and the resulting soil properties (Jenny, 1941; Buol and others, 1997; Brady and Weil, 1999). Gallatin Valley/GNF border map units are expected to share similar septic system restrictions although, based on this ecological transition zone, and the potential change in soil forming factors, the most limiting restriction could change across Gallatin Valley/GNF border. The initial investigation focused on the most limiting restriction assigned to each Gallatin Valley/GNF map unit. However, most Gallatin Valley/GNF border map units possess two to four "severe" restrictions for septic systems. Each map unit interpretation is based on seven restrictions; flooding, bedrock, ponding, depth to water, permeability, slope and large stones. Since each map unit is interpreted for seven restrictions, and each restriction is rated for three limitations ("slight", "moderate", "severe"), "severe" limitations represent only a portion of the available data. The most comprehensive method for determining percent match would compare the complete septic system interpretation for each restriction for each map unit instead of limiting the study to only the most limiting septic restriction assigned to each map unit. For this study we compared the most limiting septic restriction assigned to corresponding Gallatin Valley/GNF map units. Results for this method are presented in this study however, the comparison produced no data for the following restrictions: ponding, wetness (depth to water), poor filter and large stones.

Objectives

The objectives of this part of the study are to: 1) determine how well the septic limitation for each restriction calculated for each GNF map unit matched the corresponding septic limitation for each restriction assigned Gallatin Valley map units along the Gallatin Valley/GNF border and 2) determine the likelihood that a given soil property in the GNF soil survey, required to assess septic system limitations, can be used to assess septic system limitations. These objectives will be accomplished through analysis of the published data from the Gallatin Valley and GNF soil surveys along the Gallatin Valley/GNF border and a field investigation of four sites.

Percent Match for Most Limiting Septic Restriction

This part of the study determined how well the most limiting septic restriction, calculated for each GNF map unit, matched the most limiting septic restriction of corresponding Gallatin Valley map units. Each individual Gallatin Valley/GNF soil map unit has an assigned septic system interpretation based on the most limiting septic restriction. Figure 6 illustrates the most limiting septic restriction of the soils within Gallatin LWQD. This figure is a combination of figures 3 and 4.

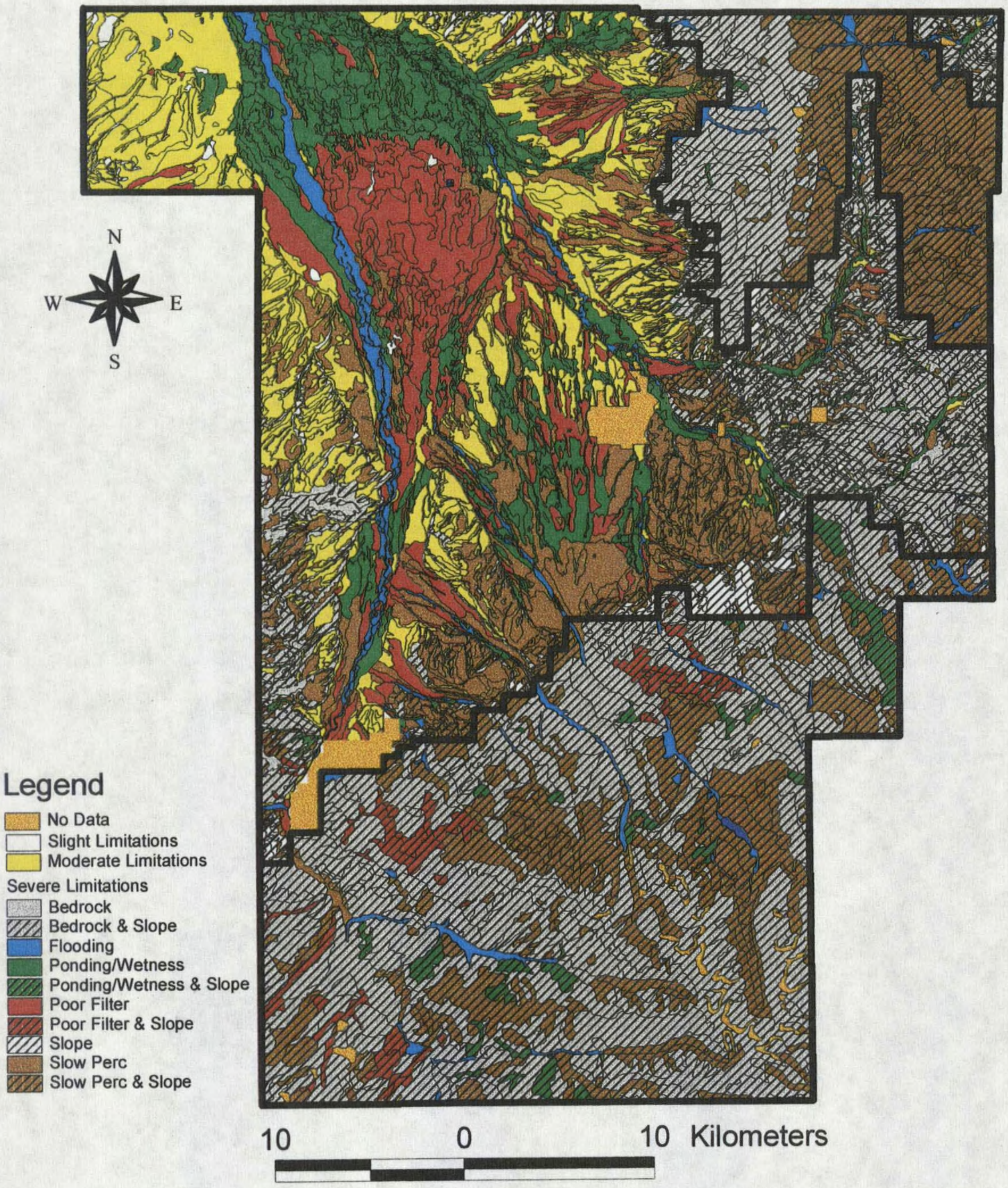

Figure 6. Most limiting septic restrictions for Gallatin Valley and GNF soils within Gallatin LWQD. Note the many mis-matches between restrictions of border Gallatin Valley/GNF map units.

Methods

I compared the most limiting septic system restriction assigned to each Gallatin Valley map unit to the most limiting septic system restriction assigned to each corresponding GNF map unit along the Gallatin Valley/GNF border. Due to different mapping scales of the two soil surveys, GNF map units are larger than Gallatin Valley map units. This results in multiple Gallatin Valley map units corresponding to a single GNF map unit along the Gallatin Valley/GNF border. Because of this scenario the septic interpretations of a single GNF map unit may be compared with septic interpretations from one or more Gallatin Valley map units. I tallied the number of most limiting septic restriction matches between corresponding Gallatin County/GNF border map units. A percent match was determined by dividing the total number of matches for each restriction for all GNF map units, by the total number of occurrences in the corresponding Gallatin Valley map units. For example, the percent match for bedrock was calculated by dividing the total number of matches in GNF (91), by the total number of occurrences in Gallatin Valley (175) and then multiplying the quotient by 100.

Bedrock, [91/175] x 100 = 52 percent match

Results and Discussion

There are 356 occurrences of Gallatin Valley map units along the Gallatin Valley/GNF border. Results for the most limiting septic restriction produced a 40 percent match between corresponding Gallatin Valley/GNF border map units. Percent match values for individual restrictions ranged from zero for "moderate", ponding, and slope, to 54 for bedrock (Table 6). These values are the result of a lack of data rather than low agreement between corresponding Gallatin Valley/GNF map units. Three restrictions (moderate, ponding, and slope) have percent match values of zero. Two

Table 6. Percent match for individual soil restrictions based on frequency of match between Gallatin Valley/GNF border map units.

Restriction	Number of Occurrences in Gallatin Valley	Number of Corresponding Matches in GNF	Percent Match
Moderate	2	0	0
Flooding	6	3	50
Bedrock	184	100	54
Ponding	4	0	0
Wetness	0	0	NA
Permeability	107	39	36
Slope	53	0	0
Large Stones	0	0	NA
Totals	356	142	40

restrictions (wetness and large stones) do not even occur in Gallatin Valley along the Gallatin Valley/GNF border. Of the remaining three, moderate and ponding have two and four occurrences each respectively. Only slope, with fifty-three occurrences, is a result of low agreement. These results are the consequence of a methodology constrained to only the most limiting septic restriction data. In order to establish a reliable comparison for each restriction between corresponding Gallatin Valley/GNF border map units, all limitation data (slight, moderate and severe) for each restriction, for each map unit, must be evaluated.

Percent Match for Individual Septic Restrictions

This part of the study determined how well individual septic system restrictions, calculated for each GNF map unit, matched septic system restrictions of corresponding Gallatin Valley map units. Each individual Gallatin Valley/GNF soil map unit has a septic system interpretation based on seven restrictions; flooding, depth to bedrock, ponding, wetness, permeability (slow perc and poor filter), slope and large stones (Table 1). A septic system limitation, (slight, moderate or severe), has been determined for each restriction.

Methods

I compared the complete septic system interpretation for individual restrictions; flooding, bedrock, ponding, wetness, permeability (slow perc and poor filter), slope and large stones, from each Gallatin Valley map unit to the complete septic system interpretation from each corresponding GNF map unit along the Gallatin Valley/GNF border. I tallied the number of matches for each restriction between corresponding Gallatin County/GNF border map units. A percent match was determined by dividing the total number of matches for each restriction (slight, moderate or severe) for all GNF map units, by the total number of chances in the corresponding Gallatin Valley map units. For example, the percent match for bedrock was calculated by dividing the total number of matches in GNF (156), by the total number of opportunities in Gallatin Valley (356) and then multiplying the quotient by 100.

Bedrock, [156/356] x 100 = 44 percent match

Results and Discussion

Results for all seven restrictions produced a 73 percent match between corresponding Gallatin Valley/GNF border map units. Percent match values for individual restrictions ranged from 32 for large stones, to 96 for wetness (Table 7). These results correspond with the more easily attainable above ground data.

Table 7. Percent match for individual soil restrictions based on frequency of match between Gallatin Valley/GNF border map units.

Soil Restriction	Number of Occurrences in Gallatin Valley	Number of Corresponding Matches in GNF	Percent Match
Flooding	356	313	88
Bedrock	356	156	44
Ponding	356	338	95
Wetness	356	343	96
Permeability	356	287	81
Slope	356	302	85
Large Stones	356	115	32
Totals	2555	.1854	73 % Avg.

High correlation for flooding, ponding, and wetness are expected due to the nature of the map units and the landforms within the Gallatin LWQD. Map units with a "severe" flooding, ponding or wetness restriction cover a small portion of the study area along the Gallatin Valley/GNF border (Figures 7, 8 and 9). These map units require the presence of water either in or on the soil. Map units located above the floodplain, and away from springs and depressions, will not indicate any presence of water either in or on the soil and possess a "slight" limitation for these restrictions. These map units account for the majority of the soils in the Gallatin LWQD and along the Gallatin Valley/GNF border. Additionally, streams in the Gallatin LWQD run perpendicular to the Gallatin Valley/GNF border. This produces similar limitations for flood restrictions between corresponding Gallatin Valley/GNF border map units. The presence, or lack of, water in a map unit, combined with the perpendicular nature of the waterways and the small areal extent of these map units, allows for a high degree of correlation for flooding, ponding, and wetness.

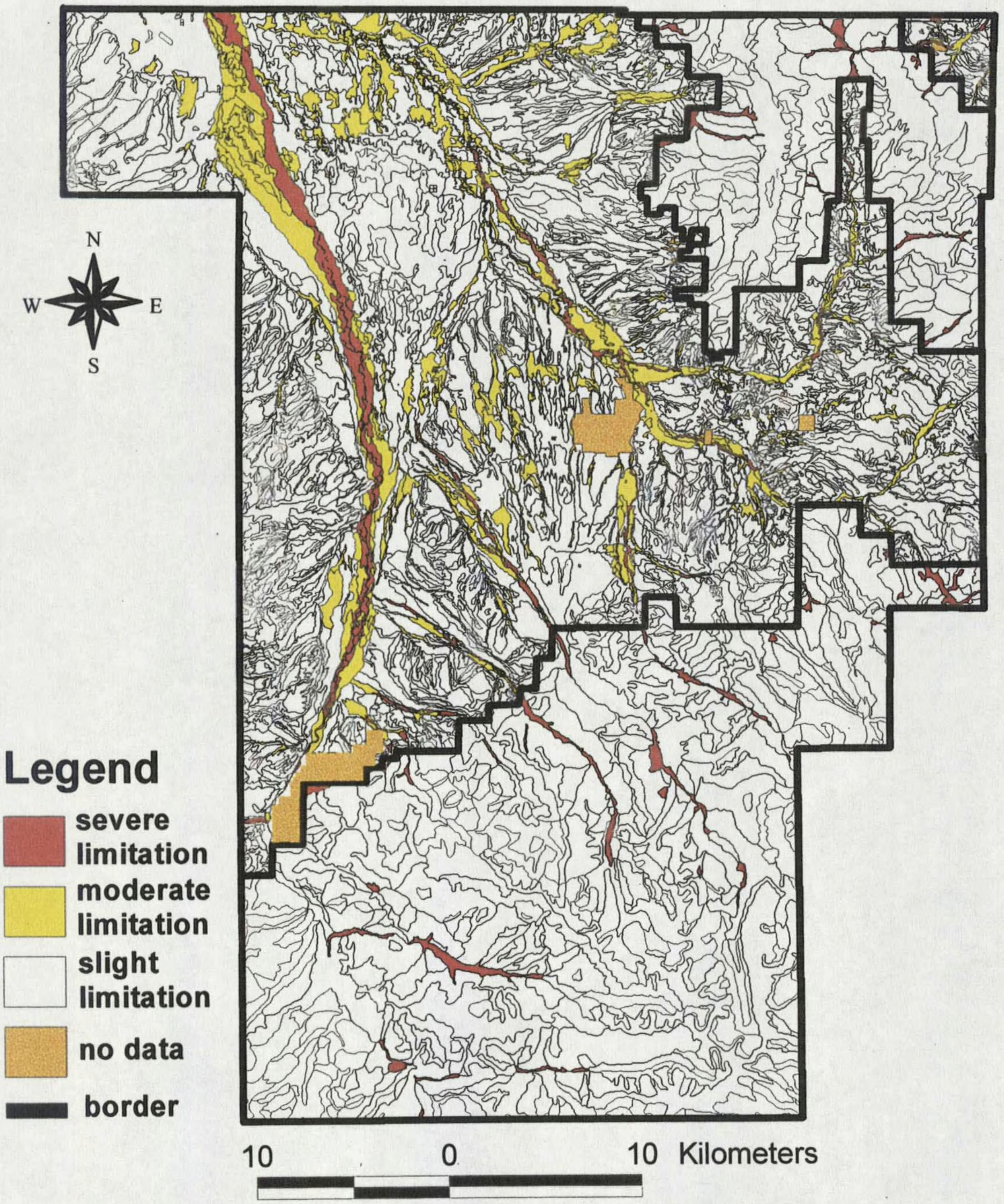

Figure 7. Flooding limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

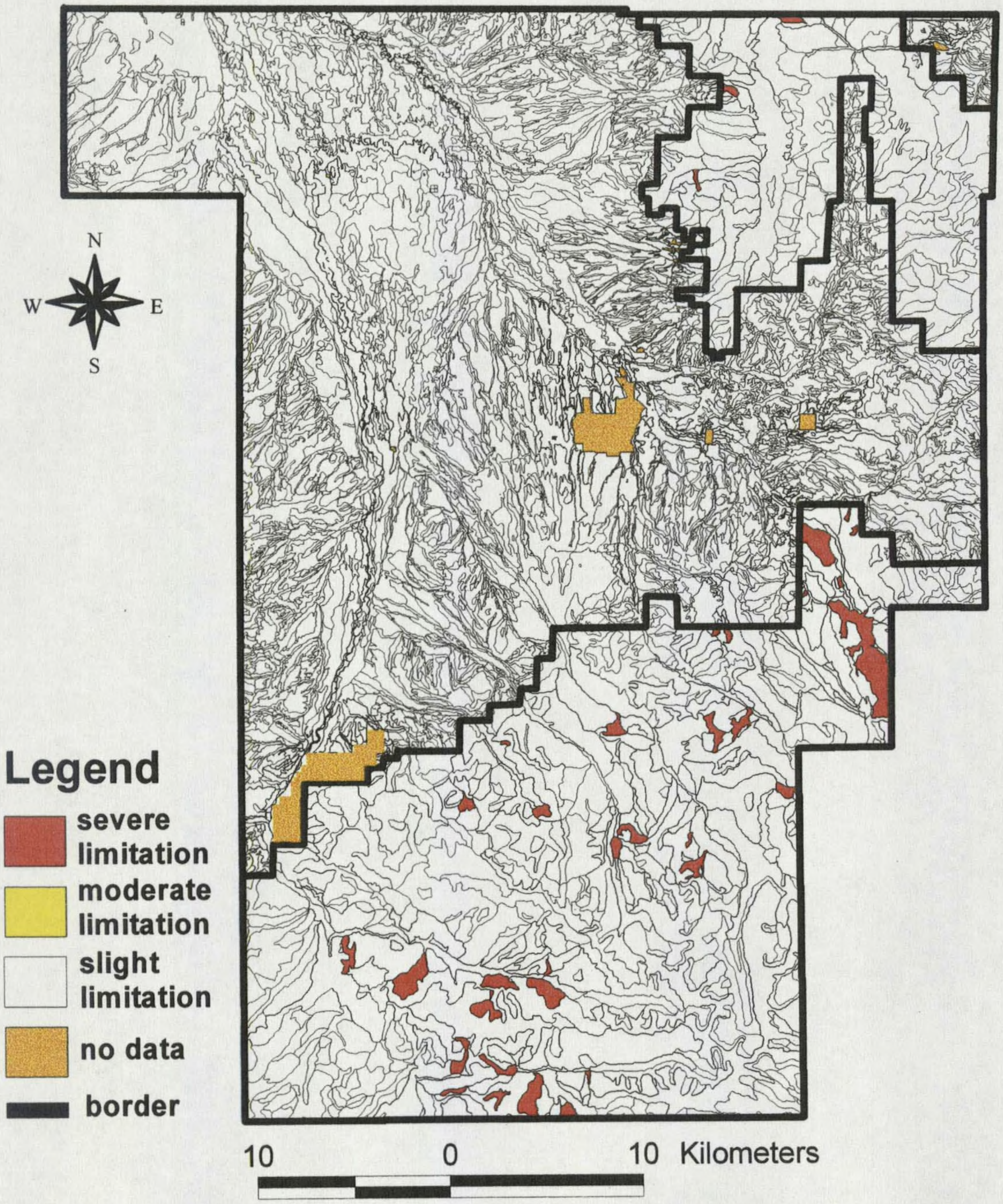

Figure 8. Ponding limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

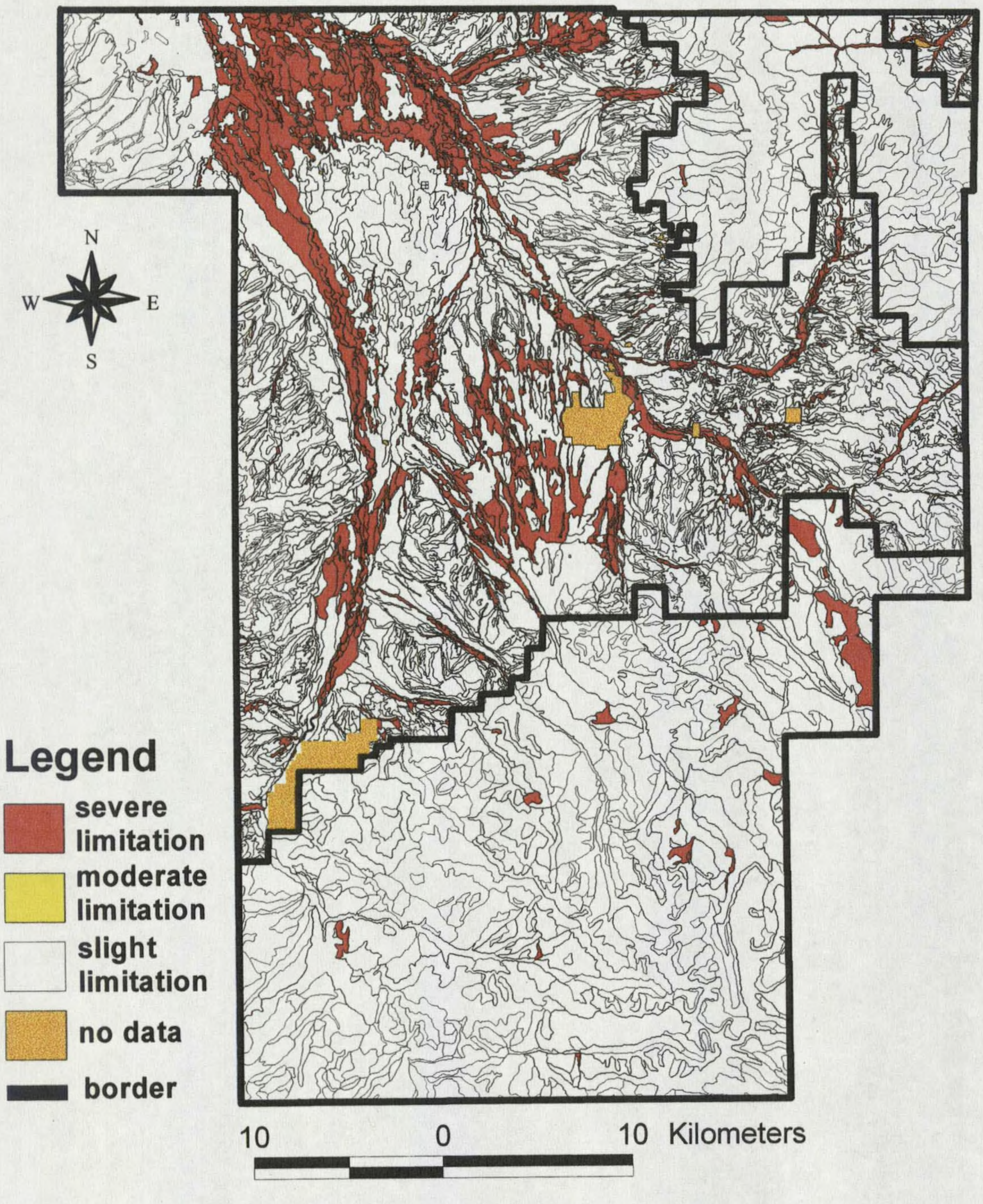

Figure 9. Wetness (depth to water) limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

Slope restrictions are also based on measurements above the soil surface. Comparison of slope restriction data produced an 85 percent match between Gallatin Valley and GNF border map units. This reflects the high slope values present along the Gallatin Valley/GNF border. Gallatin Valley map units are defined by four slope classes; 0 to 4, 4 to 8, 8 to 15 and greater than 15 percent. GNF map units are defined by seven slope classes; 0 to 10, 5 to 20, 10 to 20, 10 to 30, 10 to 45, 20 to 45, and 45 to 70 percent. Gallatin Valley slope classes have distinct breaks with no overlap while GNF slope classes cover broad ranges and have considerable overlap. The highest slope value in a class is used to determine the limitation. "Severe" limitations are assigned to slopes greater than 15 percent (Soil Survey Staff, 1993). Six out of seven GNF slope classes and one Gallatin Valley slope class have a severe limitation. Since the Gallatin Valley/GNF border defines an area of increasing slope values, and the majority of GNF map units have a severe slope restriction (Figure 10), the percent match for slope restrictions is expected to be high between corresponding Gallatin Valley and GNF border map units. GNF slope classes 10 to 20, 10 to 30, and 10 to 45 percent encompass both "moderate" and "severe" slope limitations, and slope class 0 to10 percent encompasses "slight" and "moderate" slope limitations. GNF map units require this wide range of slope values within a class because GNF map units cover large areas. While several GNF border map units contain multiple limitation slope classes, the highest slope value is used to determine the limitation. This may account for some of the mismatch along the border.

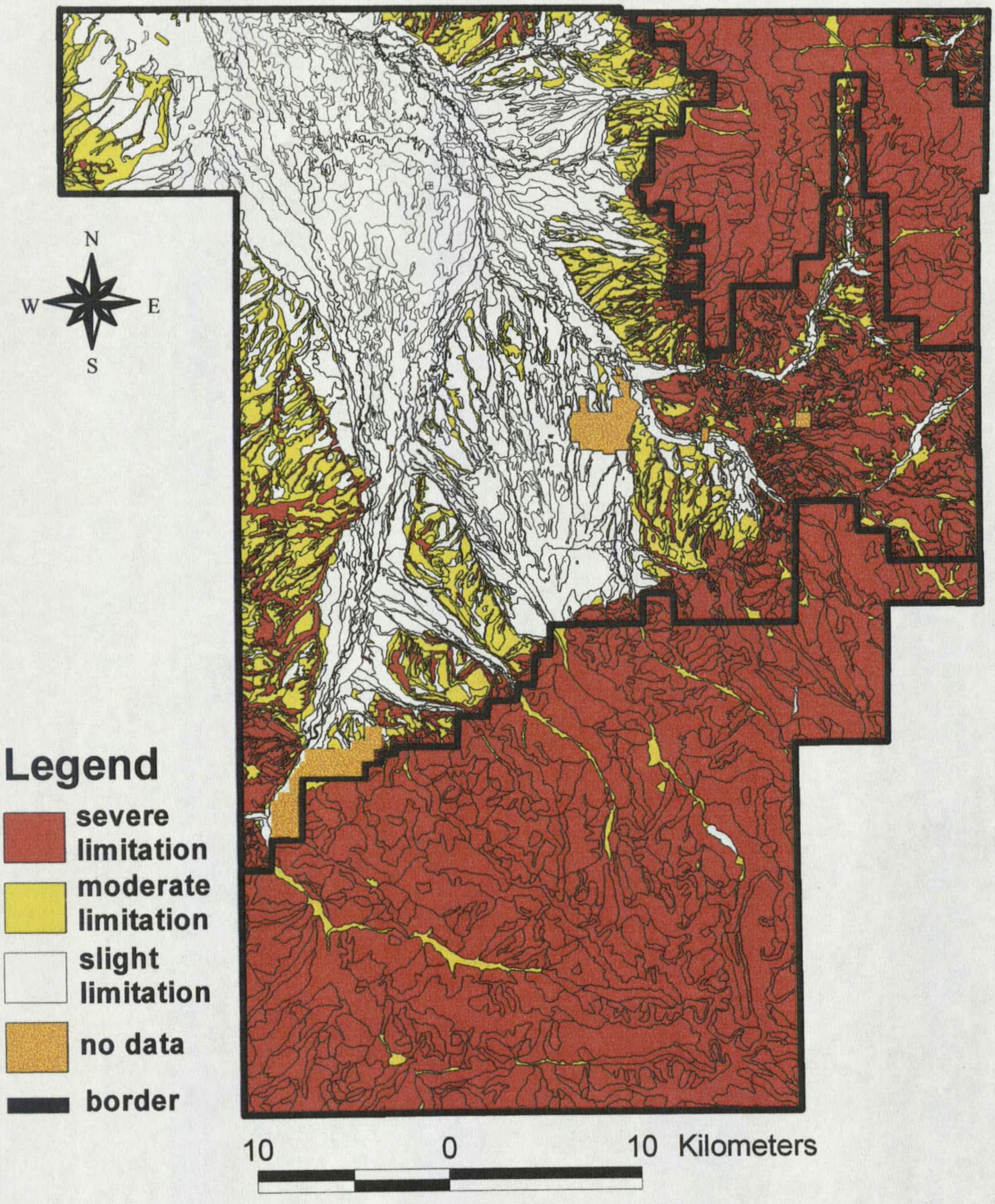

Figure 10. Slope limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

Limitations for bedrock are based on a range in subsurface soil data with similar variability. Percent match based on bedrock restriction data is 44. This reflects the range in GNF bedrock values and the difficulty involved in predicting/estimating a subsurface feature. The majority of the "moderate" and "severe" limitations for bedrock within the Gallatin LWQD occur in GNF soils (Figure 11). The GNF soil survey interim draft report defines thirteen ranges for depth to bedrock. Two ranges result in a "severe" limitation, six in a "moderate" limitation and five in a "slight" limitation. Seven ranges encompass "slight" and "moderate" limitations and one encompasses all three limitations for bedrock. The lowest/shallowest value in the range is used to determine the limitation for bedrock. The large size of GNF map units necessitates a large range in depth to bedrock values in order to adequately describe the soils within the map unit. Most of Gallatin Valley is underlain by deep alluvial deposits which produce a "slight" bedrock limitation. These alluvial deposits thin towards the surrounding mountains which define the Gallatin Valley/GNF border. "Moderate" and "severe" bedrock limitations do occur in Gallatin Valley border map units however, the majority exhibit a poor relationship between corresponding bedrock restrictions.

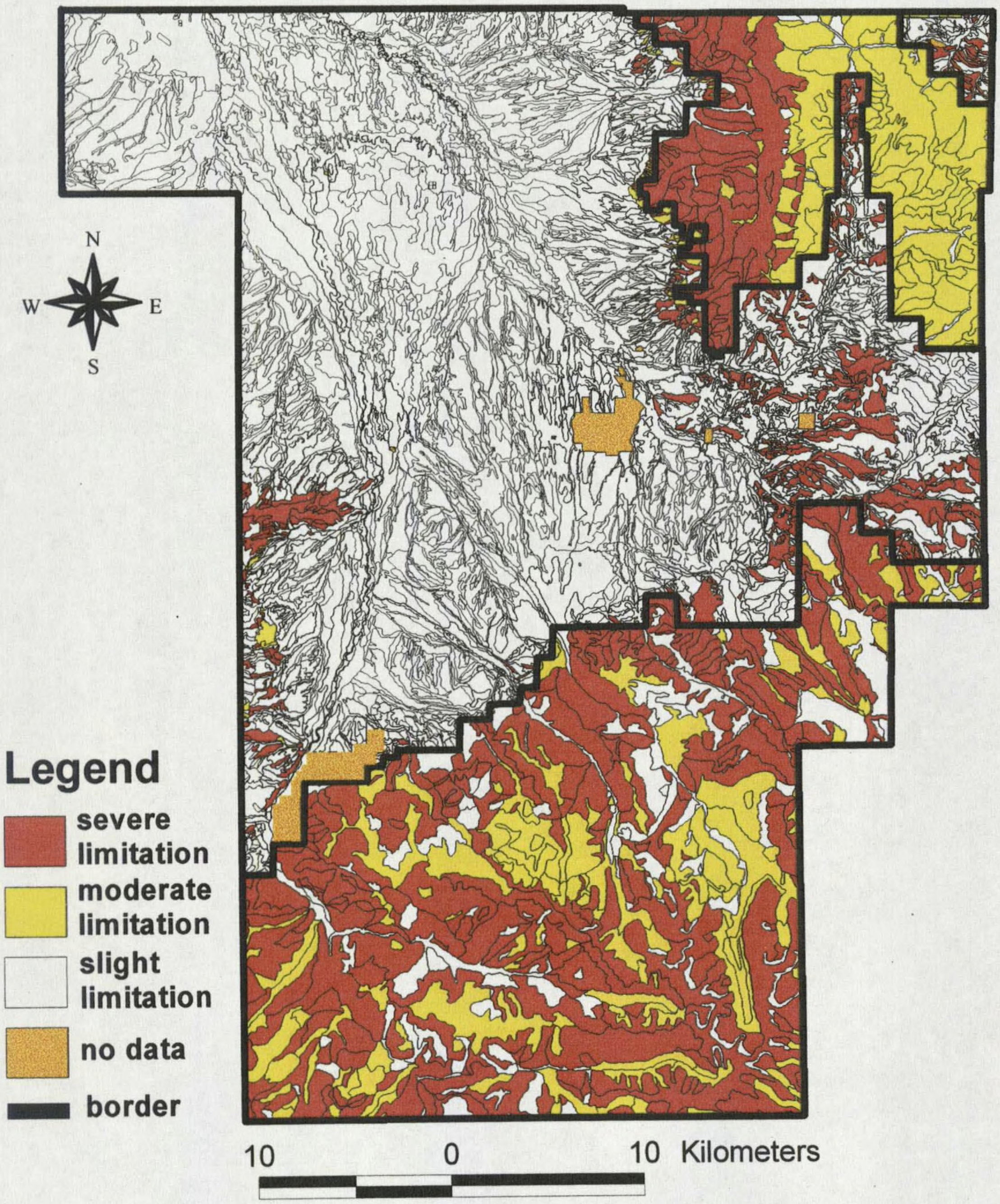

Figure 11. Bedrock limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

Permeability restrictions exhibit a greater correlation between corresponding Gallatin Valley/GNF border map units. Permeability restrictions produced an 81 percent match between corresponding Gallatin Valley/GNF border map units. This is a result of the high correlation for slow permeability restrictions along the Gallatin Valley/GNF border (Figure 12). "Severe" permeability limitations are based on fast and slow permeability values. The majority of soils within Gallatin LWQD exhibit a "severe" permeability limitation for slow percolation and form a seamless boundary between corresponding Gallatin Valley/GNF border map units. A significant portion of the Gallatin LWQD also shows a "severe" permeability limitation for fast percolation (Figure 13) however, the boundary is defined by "severe" permeability limitations in GNF soils and "slight" permeability limitations in Gallatin Valley soils. A considerable number of soils within the Gallatin LWQD contain dual "severe" permeability limitations (slow perc and poor filter). This reflects the high number of associations and complexes within Gallatin Valley and GNF map units. GNF map units contain soil complexes, associations and a few consociations. Most are mapped at the family level of taxonomy with a few mapped at higher levels (Davis and Shovic, 1996). Gallatin Valley map units contain soil complexes, associations and consociations mapped at the series level of taxonomy. Associations and complexes are map units that contain two or more soil components that may possess different soil properties (Soil Survey Staff, 1993). This results in contrasting interpretations within the same map unit.

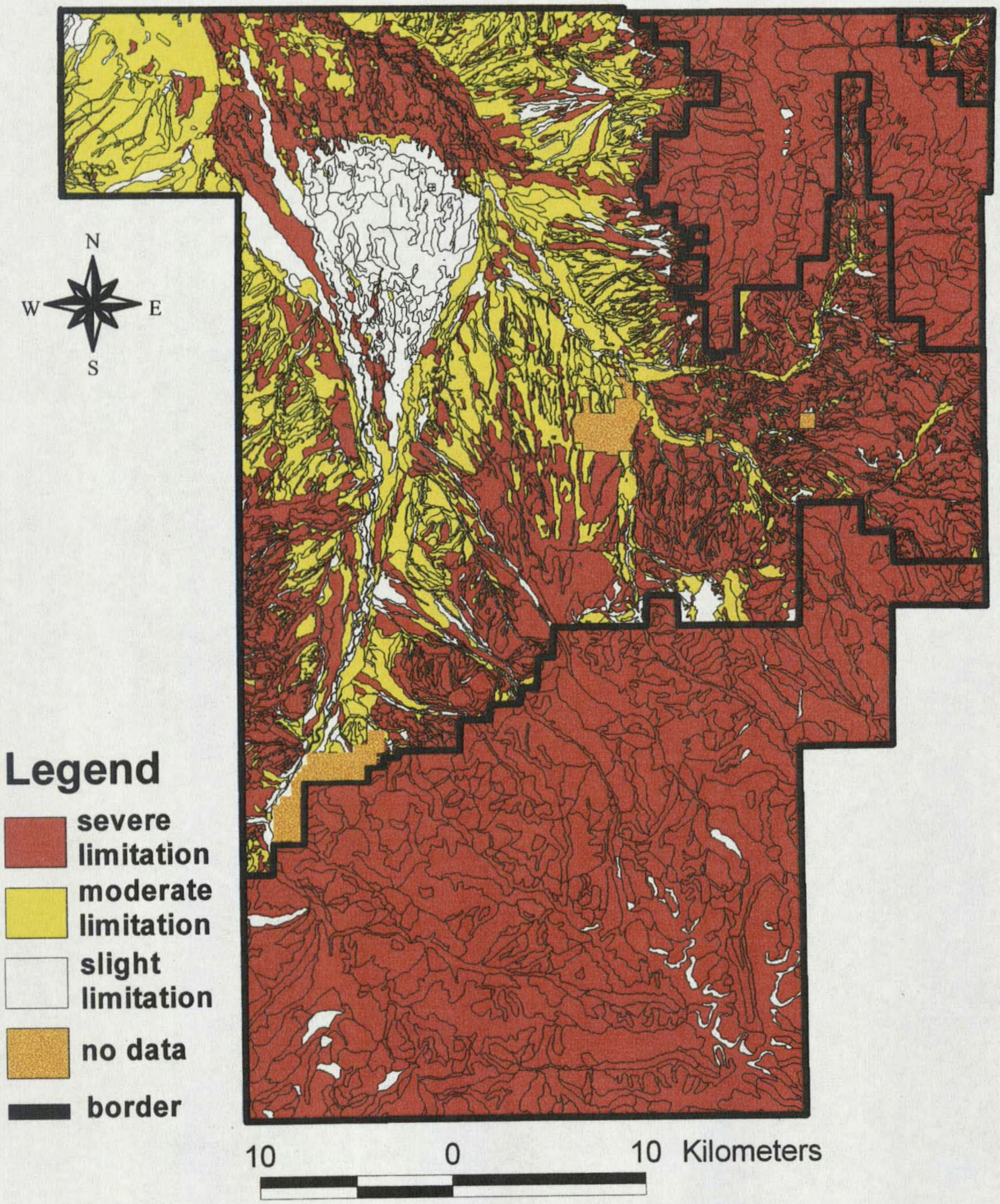

Figure 12. Slow permeability limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

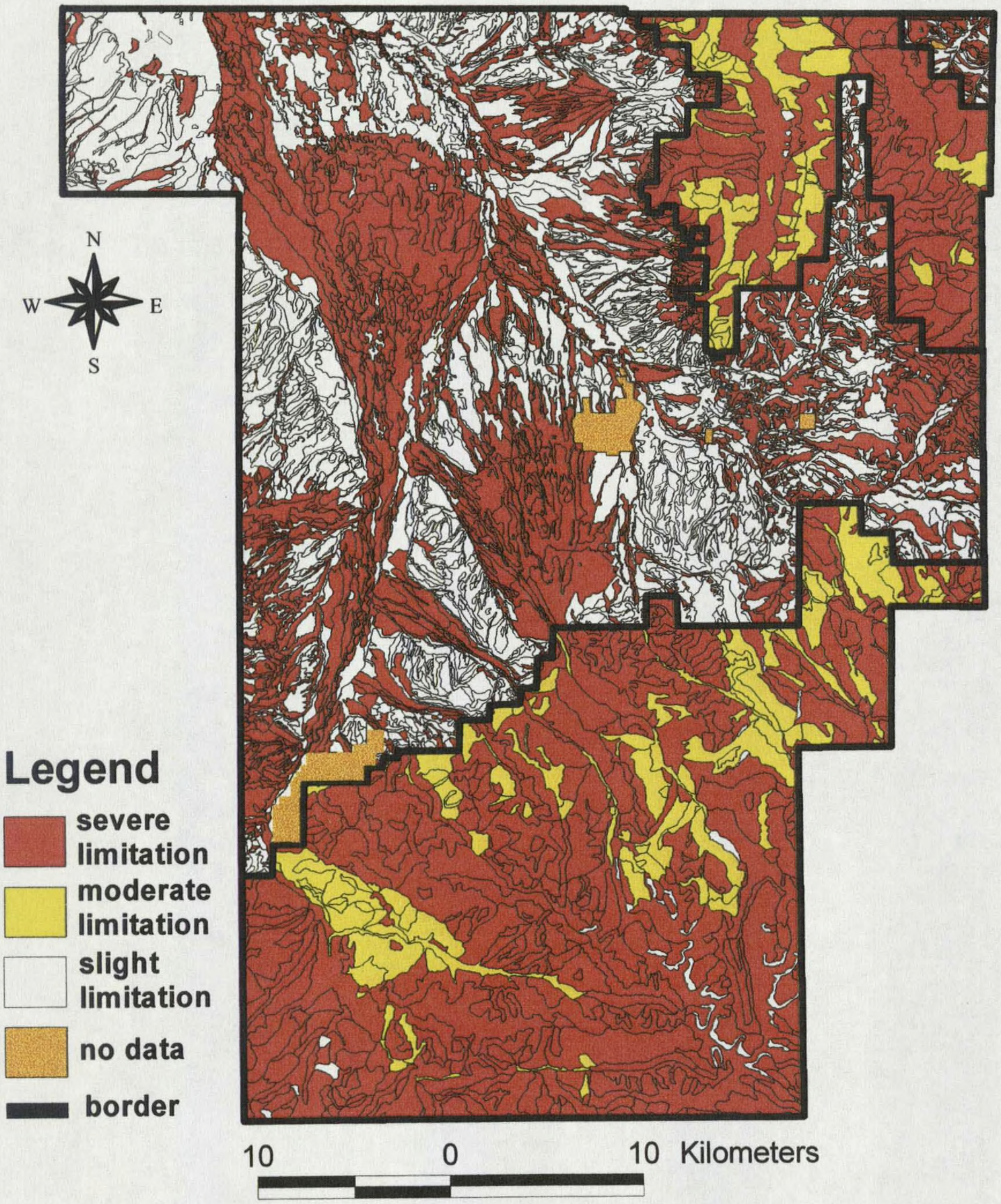

Figure 13. Fast permeability limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

Severe limitations for large stones are more common in GNF soils than Gallatin Valley soils. Gallatin Valley/GNF border map units produced a 32 percent match for large stone restrictions. "Severe" limitations are assigned to soils that contain more than 50 percent large stones (greater than 76 mm) on a weighted average to a 1 m depth. Stones of this size and amount generally occur in higher elevation, bedrock controlled landscapes. These areas are more common in GNF than Gallatin Valley. Stones of this size are found throughout Gallatin Valley but not in a quantity to warrant a "severe" limitation. Except for a few locations in Gallatin Valley along the western side of the Bridger mountains, "severe" limitations for large stones are found only on the flanks of the Bridger and Hyalite mountains in GNF (Figure 14). The Gallatin Valley/GNF border is defined by a series of mis-matches for large stone restrictions. "Severe" limitations occur in GNF and "slight" limitations in Gallatin Valley, except along the border in the northeast and east central portions of the LWQD defined by "slight" limitations on both sides of the border.

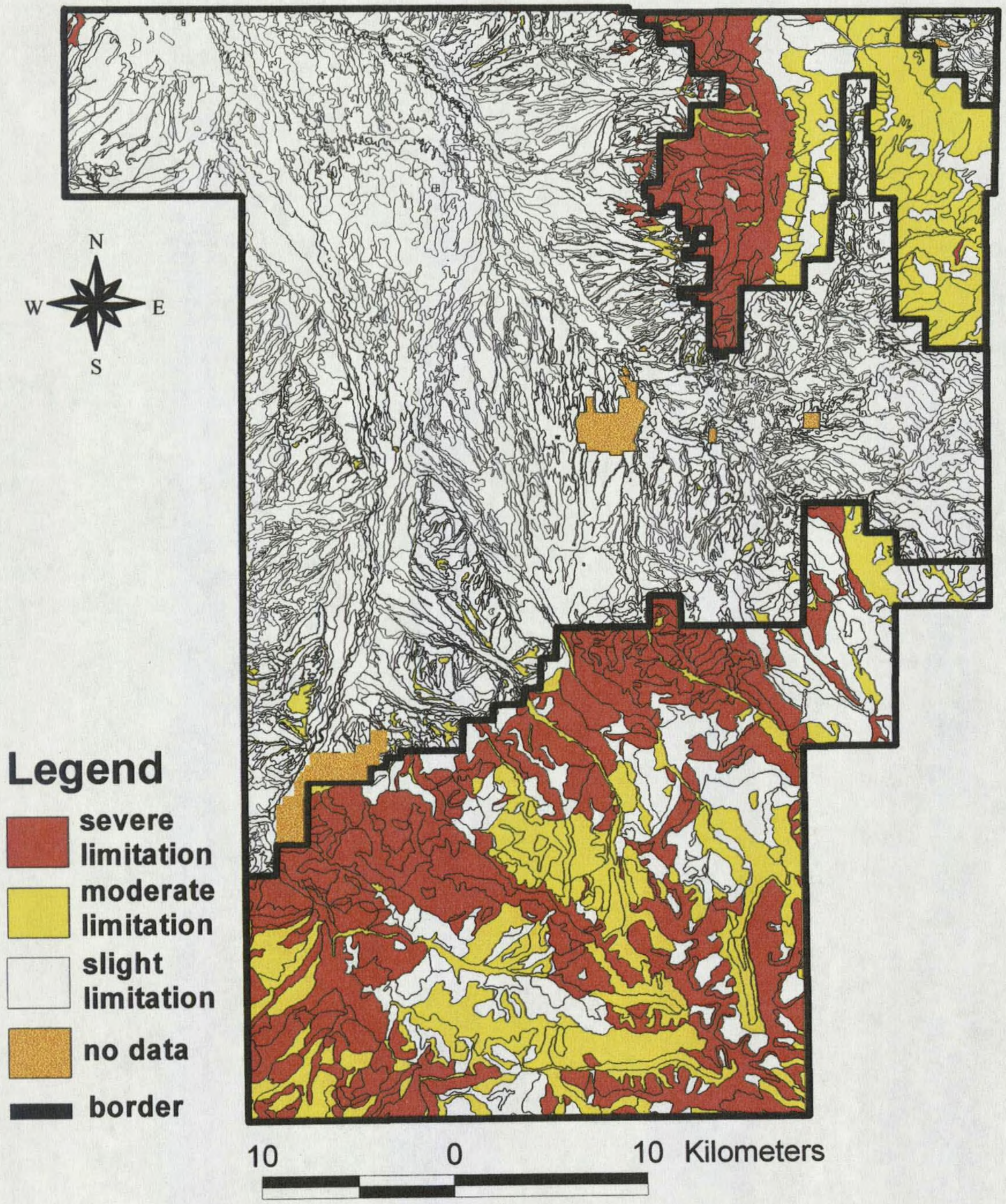

Figure 14. Large stone limitations for Gallatin Valley and GNF soils within the Gallatin LWQD.

Percent Match for GNF Border Map Units Based on the Weighted Average Calculation

This part of the study compared the percent match between Gallatin Valley/GNF border map units based on; 1) the percent match between septic system interpretations and, 2) the percent linear length composition that border Gallatin Valley map units comprise in corresponding GNF map units. The second order Gallatin Valley soil survey is a larger scale soil survey than the third order GNF soil survey (1:24,000 vs 1:63,360). A larger scale allows for smaller map unit delineations. This results in multiple Gallatin Valley map units describing soils covered by a single GNF map unit. These multiple map units may contain contrasting septic system interpretations within a single GNF map unit. This situation is present along the Gallatin Valley/GNF border. For this reason, I weighted each Gallatin Valley map unit according to its percent linear composition within its corresponding GNF map unit. Percent match results showed high correlation between corresponding Gallatin Valley/GNF border map units. Since multiple Gallatin Valley map units, with contrasting septic system interpretations, are required to describe a single GNF map unit, percent match values between corresponding Gallatin Valley/GNF border map units should be weighted. Results are expected to adjust percent match values and produce a refined interpretation of the relationship between corresponding Gallatin Valley/GNF border map units.

Methods

Each GNF map unit along the Gallatin Valley/GNF border was assessed to determine the percent match with the corresponding Gallatin Valley map unit. Gallatin Valley map units were weighted according to: 1) the linear length composition that the Gallatin Valley map unit makes up in a corresponding GNF map unit and, 2) the septic system interpretation percent match between corresponding Gallatin Valley/GNF border map units. This method assumes the septic interpretations of Gallatin Valley map units are correct because it is a more detailed and larger scale soil survey designed to be interpreted for on-site sewage disposal systems.

Gallatin Valley and GNF soil surveys were mapped by different individuals. No two individuals draw a boundary on a map exactly the same. Since the two surveys were mapped by different individuals, map unit boundaries along the Gallatin Valley/GNF border do not always line-up. For this reason I used the adjusted ArcView™ coverages that resolved this problem and provided continuity between border map unit boundaries.

The Gallatin Valley/GNF ArcView™ coverage files were downloaded into an ArcView™ software program. Linear length measurements for each Gallatin Valley and GNF map unit were measured on-screen with the linear measuring tool provided in the software.

Percent match values were calculated by comparing the septic system limitations for each soil restriction between corresponding Gallatin Valley/GNF map units. This method was applied to each Gallatin Valley/GNF border map unit.

Figure 15 illustrates an area along the Gallatin Valley/GNF border. At this location GNF map unit 64-2A corresponds with three Gallatin Valley map units; 294D, 814D, and 294E. The linear distance between points A - E is equal to 1000 m and represents the total linear length for GNF map unit 64-2A. The linear distance for each Gallatin Valley map unit is: (A-B) = 70 m, (B-C) = 420 m, (C-D) = 120 m, and (D-E) = 390 m. The linear composition for each corresponding Gallatin Valley map unit is:

294E (A-B) + (D-E) = 70 m + 390 m = 460 m

294D (B-C) = 420 m

814D (C-D) = 120 m

The linear length proportion for each Gallatin Valley map unit is:

294E (A-B) + (D-E) = [460 m/1000.0 m] = 0.46

294D (B-C) = [420 m/1000.0 m] = 0.42

814D (C-D) = [120 m/1000.0 m] = 0.12

Each map unit contains a septic system interpretation for seven restrictions: flooding, bedrock, ponding, wetness, permeability, slope and large stones (Table 8). Permeability may rate "severe" for fast (poor filter) or slow (slow perc) permeability values. The septic system interpretations for GNF map unit 64-2A matched four septic system interpretations for Gallatin County map units 294D and 814D (ponding, wetness, permeability and slope) and three septic system interpretations for Gallatin Valley map unit 294E (ponding, wetness and permeability). The proportion for each map unit based on a total of seven restrictions is:

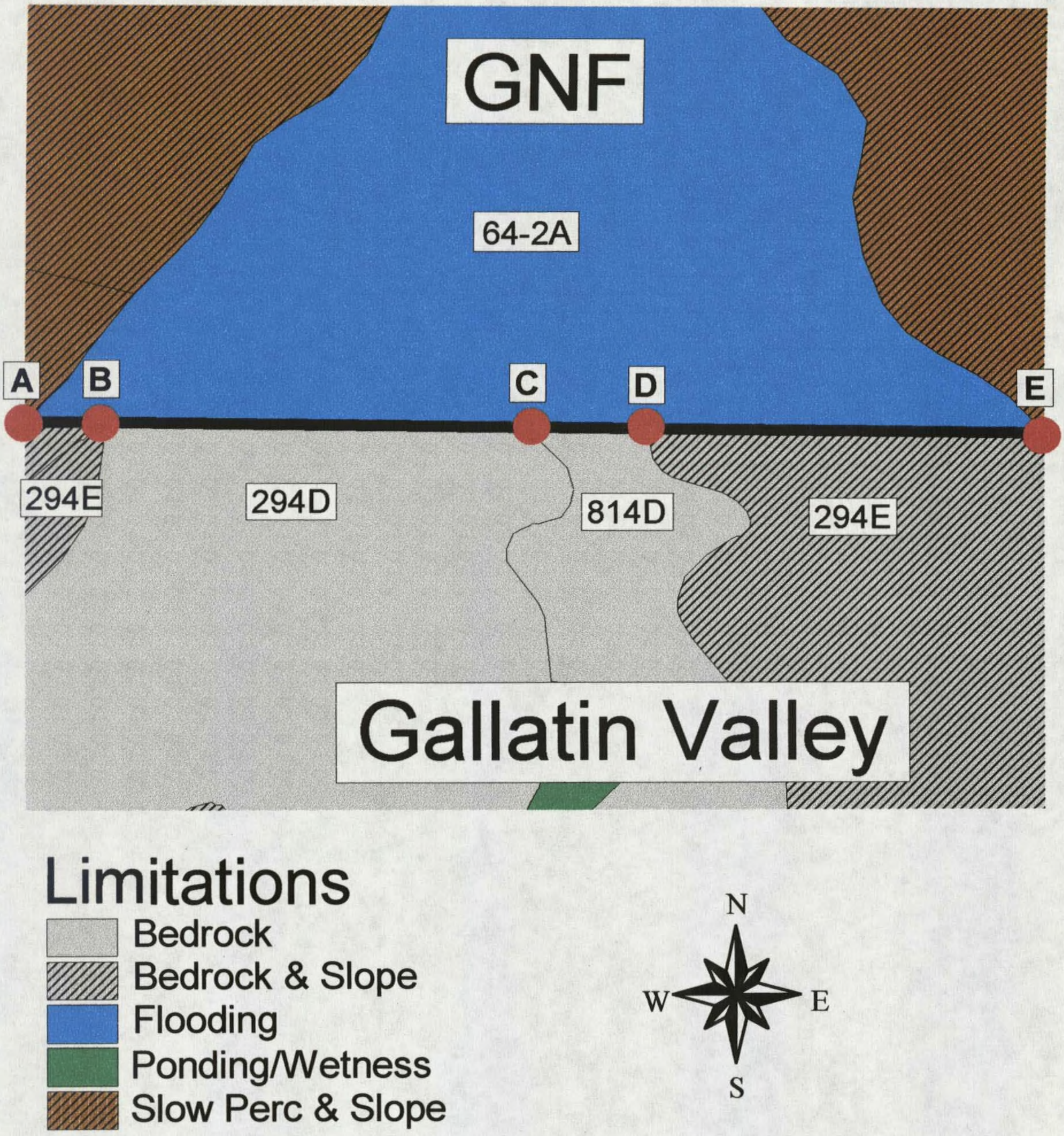

Figure 15. Intersection along the Gallatin Valley/GNF border between Gallatin Valley map units 294E, 294D and 814D and GNF map unit 64-2A.

294E (3/7) = 0.43

294D (4/7) = 0.57

814D (4/7) = 0.57

The contribution for each map unit is determined by multiplying the linear length proportion by the corresponding septic system interpretation proportion. The contribution for each map unit is:

294E, [0.46 x 0.43] = 0.20

294D, [0.42 x 0.57] = 0.24

814D, [0.12 x 0.57] = 0.07

Table 8. Septic system interpretations for Gallatin Valley map units 294D, 294E, 814D and GNF map unit 64-2A.

	GNF	**Gallatin Valley**		
	64-2A	**294D**	**294E**	**814D**
Restriction	**Limitations**			
Flooding	severe	slight	slight	slight
Bedrock	slight	severe	severe	severe
Ponding	none	none	none	none
Wetness	slight	slight	slight	slight
Permeability	slow perc	slow perc	slow perc	slow perc
Slope	moderate	moderate	severe	moderate
Large Stones	moderate	slight	slight	slight

The total contribution for this occurrence of GNF map unit 64-2A is:

$$[0.20 + 0.24 + 0.07] = 0.51$$

The total adjusted contribution of the original 1000 m linear length is:

$$[0.51 \times 1000 \text{ m}] = 510 \text{ m}$$

This represents a 510 meter contribution from the original 1000 meters for this one occurrence of GNF map unit 64-2A. This calculation was performed for all Gallatin Valley/GNF border map units.

Results and Discussion

Thirty-three GNF and ninety-two Gallatin Valley soil mapping units define the Gallatin Valley/GNF border. Multiple occurrences of these map units along the border result in a total of 356 Gallatin Valley and 170 GNF map units. Overall agreement between border Gallatin Valley/GNF map units increased from 73 to 75 percent using the weighted average calculation (Table 9.). These results indicate a high level of agreement between septic system interpretations of corresponding Gallatin Valley/GNF border map units. Percent match values for individual GNF map units varies from 52 to 100 percent based on the weighted average calculation (Table 10). Fourteen GNF border map units have percent match values ≥ 80 percent and four of five GNF map units with ten or more occurrences have percent match values greater than 72 percent. Map units 71-1D and 87-2C have 100 percent match with their corresponding Gallatin Valley map units. Although these are based on one and two occurrences respectively, the 87-2C result is

Table 9. Adjusted border length based on percent match values using the weighted average calculation.

Gallatin Valley/GNF Border Length		Percent Match
Initial (km)	**Adjusted (km)**	
133.5	**100.6**	**75**

Table 10. GNF border map units, number of occurrences and percent match results based on the weighted average calculation.

Map Unit	n	Percent Match	Map Unit	n	Percent Match
46-1B	2	70	84-2B	5	72
54-1A	22	84	85-2A	6	76
54-1B	3	84	85-2B	10	79
54-1C	15	72	85-3A	10	73
54-1G	5	66	85-3B	8	74
54-2B	3	85	86-2A	2	87
54-2C	5	71	86-2C	6	77
54-2D	4	65	86-2D	4	68
54-2E	1	72	86-3B	1	86
64-2A	6	53	86-3C	2	86
64-2C	14	52	87-1B	2	83
66-1A	1	71	87-2A	3	80
71-1A	5	65	87-2B	5	83
71-1D	1	100	87-2C	2	100
71-1E	4	88	87-2D	3	85
82-2B	5	80	91-2B	1	71
84-1A	3	74			

significant because it shows repeatability. Three different Gallatin Valley map units make up each occurrence of GNF map unit 87-2C. This suggests that although GNF map units cover a broader area than Gallatin Valley map units, some GNF map units may accurately represent the variability found within the map unit.

Field Investigation

An underlying assumption in this study is that the Gallatin Valley soil survey more accurately reflects soil conditions along the Gallatin Valley/GNF border than the GNF soil survey. Gallatin Valley soil survey is a lower order, and therefore, a larger scale and more detailed soil survey than the higher order GNF soil survey. However, since the border between the two surveys roughly defines an ecological transition zone, Gallatin Valley map units may not adequately represent the soils across the Gallatin Valley/GNF border. Roughly one third of the most limiting septic system restrictions between Gallatin Valley/GNF border map units do not match (Figure 6). Since Gallatin Valley/GNF border map units contain contradicting septic system interpretations across an artificial boundary, each survey must be examined to determine if one is more representative of soil conditions along the Gallatin Valley/GNF border. A field investigation at four sites along the Gallatin Valley/GNF provided the data to address this problem.

Methods

Gallatin Valley/GNF Border

Four sites along the Gallatin Valley/GNF border were selected for field investigation of the septic system limitation. Site selection was based on the following criteria: 1) the septic system limitation of corresponding Gallatin Valley/GNF border map units must be different and, 2) permission to access the sites on private property must be attainable. Figure 16 shows the location of Stone Creek, Olson Creek, Bridger and Hodgman Canyon field sites. Appendix C contains a detailed description for each field site. Six soil pits were dug at each site, three each in Gallatin Valley and GNF map units. Sites within each map unit were randomly selected within a 100 m distance of the Gallatin Valley/GNF border and 10 m from any human disturbance such as roads or trails. Each soil pit was dug to a depth of 1.8 meters or bedrock/cemented pan, whichever occurred first. The following information was collected at each site:

1. Depth to bedrock, cemented pan and water table, where measurable.
2. Presence and depth to redoximorphic features.
3. Percent slope.
4. Percent coarse fragments >76 mm, on a volume basis, for each horizon to a 1.0 m depth.
5. Soil texture and structure for each horizon between 0.6 - 1.5 m.
6. Landform type and landscape position.
7. Presence of hydrophytic vegetation.

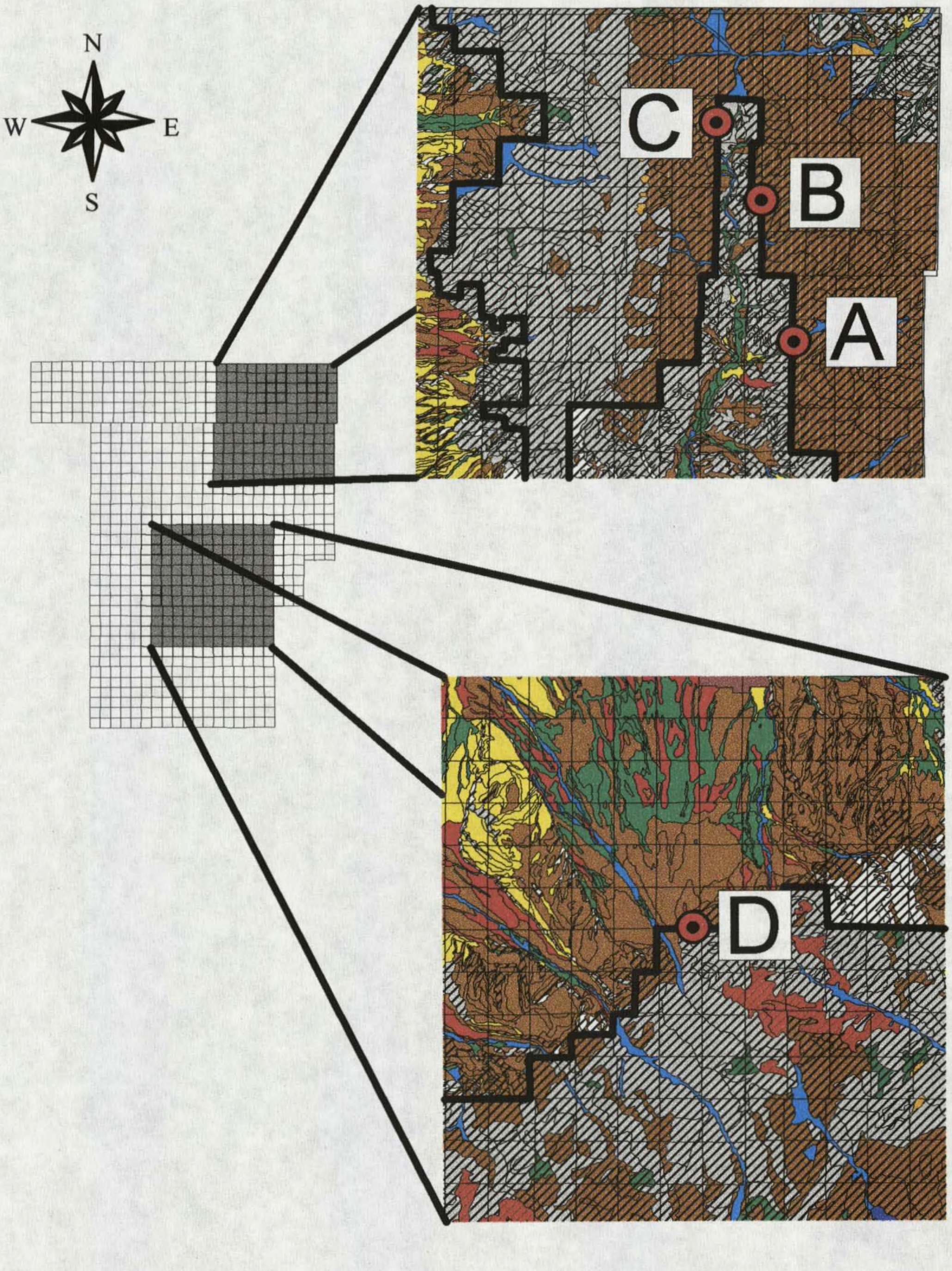

Figure 16. Location of Stone Creek (A), Olson Creek (B), Bridger (C) and Hodgman Canyon (D) field sites within the Gallatin LWQD.

Depth to bedrock and cemented pan were measured from the top of the surface mineral horizon to the top of bedrock/cemented pan. Depth to water table was measured from the top of the surface mineral horizon to the top of free water in the soil pit. Depth to water table, when not evident, was inferred by the presence of redoximorphic features in the soil profile (Simonson and Boersma, 1972; Vepraskas and others, 1974; Bouma, 1983; Franzmeier and others, 1983; Vepraskas and Wilding, 1983; Pickering and Veneman, 1984; Vepraskas, 1996).

Estimates of a soil's susceptibility to ponding were made according to Part 618.46 of the National Soil Survey Handbook. Ponding potential for each soil pit was evaluated on a binary (+/-) basis based on landform, soil and vegetation data. Landform features subject to ponding include closed drainage systems, potholes and backswamps (Soil Survey Staff, 1993). Soil properties indicative of ponding include: 1) a dark surface horizon overlying a gleyed subsoil, 2) many prominent redoximorphic features with low value and chroma, 3) capillary transport and concentrations of carbonates and sulfates, or both, in the upper soil horizons, and 4) dark colors and high levels of organic matter throughout the profile or any combination of these features. Vegetation common to ponded areas include facultative hydrophytes such as willows and sedges (Soil Survey Staff, 1993).

Soil texture samples were collected from each horizon between a 0.6 - 1.5 meter depth and the accompanying soil structure recorded. Texture samples were weighed and oven dried until sample weight remained constant. Particle size analysis as outlined by Gee and Bauder (1979), was performed on each sample to obtain the USDA soil textural class. Soil permeability classes were assigned to each horizon based on the USDA-NRCS field guide for determining relative permeability (Table 4). Permeability values corresponding to permeability classes were assigned based on section 618.44b of the USDA-NRCS National Soil Survey Manual. Section 618.44b assigns a permeability range to each permeability class (Table 5). "Severe" permeability restrictions occur above 15.0 (cm/hr) and below 1.5 (cm/hr). The most limiting value in the range was used to calculate the septic system limitation for permeability. For example, the moderate permeability class has values that range from 1.5 - 5.1 (cm/hr). The most limiting value in this range is 1.5 (cm/hr) and results in a "severe" limitation for septic systems due to a slow permeability (slow perc). Conversely, the moderately rapid permeability class has values that range from 5.1 - 15.2 (cm/hr). The most limiting value in this range is 15.2 (cm/hr) and results in a "severe" limitation for septic systems due to a high permeability value (poor filter).

Percent slope was measured using the inclinometer in a Silva Ranger compass. Two slope measurements were taken at each soil pit, one upslope and one downslope of the soil pit. The two values were averaged to determine the septic system limitation for percent slope.

Percent coarse fragments > 76 mm were estimated in the field on a volume basis for each horizon to a 1.0 meter depth. The volume figure was converted to a percent by weight using USDA-NRCS Conversion Table 618-11 (Table 11). The weighted average value for each horizon to a 1.0 meter depth was calculated to determine the septic system limitation for large stones as described earlier.

Table 11 Percent by weight conversion based on percent by volume, after USDA-NRCS exhibit 618-11 (Soil Survey Staff, 1993).

Percent by Volume	Percent by Weight	Percent by Volume	Percent by Weight
3	5	35	50
7	10	40	55
10	15	45	60
13	20	50	65
16	25	56	70
20	30	62	75
23	35	68	80
27	40	74	85
31	45	80	90

Proportions

To determine how well a given soil property in either soil survey will reflect true field conditions I compared the septic system interpretations from twenty-four soil pits to the septic system interpretation assigned to the soil map unit from the corresponding Gallatin Valley and GNF soil surveys. Field data for each restriction was compared to the published data from Gallatin Valley and GNF soil surveys. Field data was then separated into Gallatin Valley and GNF data sets and compared to data from each survey. A proportion, p, was calculated for each restriction based on the number of matches with both Gallatin Valley and GNF soil surveys. For example, nineteen of twenty-four field permeability values matched the corresponding values in the GNF soil survey. The proportion, p, based on this comparison is; $p = 0.79$.

Results and Discussion

All twenty-four soil pits from four field sites rated "severe" for on-site sewage disposal (Table12). Additionally, all but three possess multiple "severe" restrictions. Results show the assigned septic restriction based on field data has better agreement with GNF data than Gallatin Valley data. Assigned septic restrictions from seventeen soil pits agreed with GNF data while only four agreed with Gallatin Valley data. This produced a 71 percent match with GNF data and a 17 percent match with Gallatin Valley data. Appendix D lists the value and limitation for each restriction for all twenty-four soil pits.

Proportion values for each restriction vary based on comparison with Gallatin Valley and GNF soil survey data (Table 13.). Overall proportions are greatest when the field data is combined and compared to GNF survey data, $p = 0.77$ vs $p = 0.65$. Figure 17 illustrates the percent match of the combined field data with Gallatin Valley and GNF survey data for each restriction. There is high agreement between field data and data from both surveys for flooding, ponding and wetness. This reflects more on what is not present than what is present. Sixty-three of seventy-two field data results for flooding, ponding and wetness produced "slight" limitations. Field data for ponding shows one-hundred percent agreement, $p = 1.00$, with data from both soil surveys. Ponding limitations are based on a binary, (+/-), basis, the soil either ponds or it does not. All twenty-four soil pits exhibited no potential to pond resulting in a "slight"limitation for ponding. Similar results were produced for flooding and wetness.

Table 12. Most limiting septic system interpretation for twenty-four field soil pits based on field, Gallatin Valley, and GNF data. Pits A-C represent GNF field locations, pits D-E represent Gallatin Valley field locations.

Location		**Most Limiting Septic System Interpretation**		
Site	**Pit**	**Field Data**	**Gallatin Valley Data**	**GNF Data**
Stone Creek	A	slow perc	ponding/wetness	flooding
	B	slow perc	ponding/wetness	flooding
	C	slow perc	ponding/wetness	flooding
	D	flooding	ponding/wetness	flooding
	E	flooding	ponding/wetness	flooding
	F	flooding	ponding/wetness	flooding
Olson Creek	A	slow perc	bedrock	slow perc
	B	bedrock	bedrock	slow perc
	C	bedrock	bedrock	slow perc
	D	slow perc	bedrock	slow perc
	E	bedrock	bedrock	slow perc
	F	slow perc	bedrock	slow perc
Bridger	A	slow perc	bedrock	slow perc
	B	slow perc	bedrock	slow perc
	C	slow perc	bedrock	slow perc
	D	slow perc	bedrock	slow perc
	E	bedrock	bedrock	slow perc
	F	slow perc	bedrock	slow perc
Hodgman Canyon	A	bedrock	slow perc	bedrock
	B	bedrock	slow perc	bedrock
	C	bedrock	slow perc	bedrock
	D	bedrock	slow perc	bedrock
	E	bedrock	slow perc	bedrock
	F	bedrock	slow perc	bedrock

Table 13. Proportion values for individual restrictions based on comparison of field data with corresponding Gallatin Valley and GNF soil survey data. Twenty-four possible matches for each restriction at each field site except where noted. One hundred and sixty-three total possible matches.

	Number of Matches with:		Proportion (p) based on:	
Restriction	**Gallatin Valley Soil Survey**	**GNF Soil Survey**	**Gallatin Valley Soil Survey**	**GNF Soil Survey**
Flooding	18	21	0.75	0.88
Bedrock	10	14	0.42	0.58
Ponding	24	24	1.00	1.00
Wetness	21	21	0.88	0.88
Permeability *	12	14	0.63	0.74
Slope	15	15	0.63	0.63
Large Stones	6	10	0.25	0.42
Total	106	119	0.65	0.73

* Results based on nineteen observations.

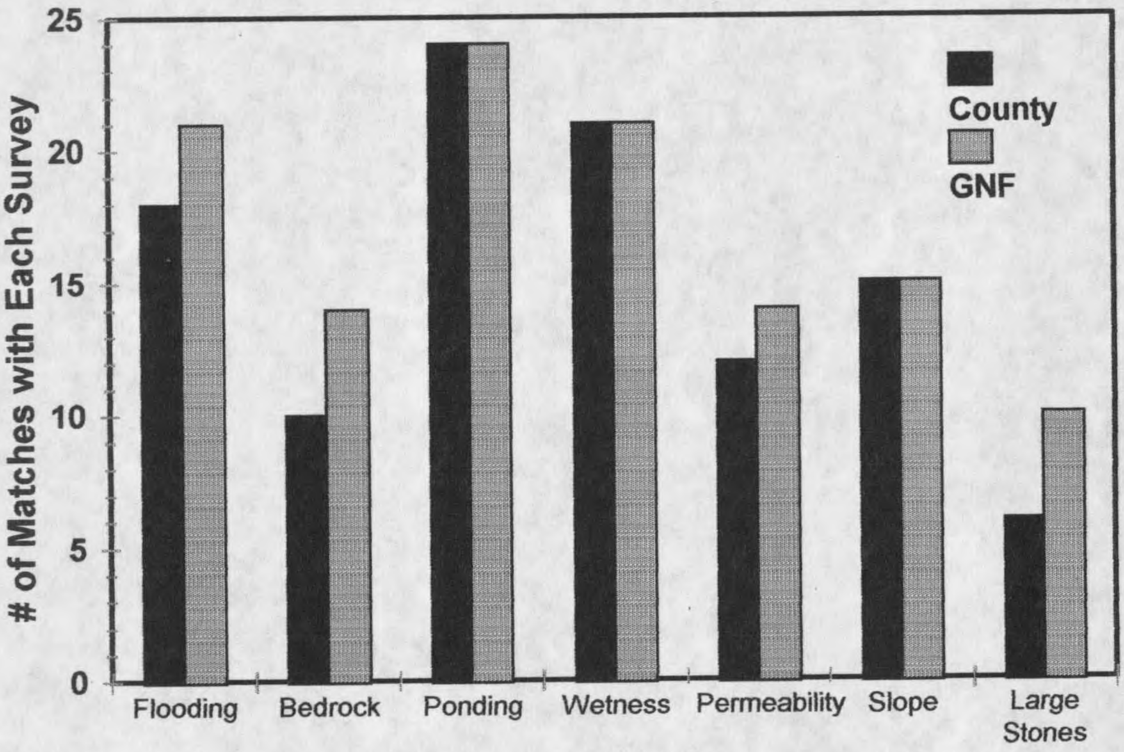

Figure 17. Number of matches for each restriction based on a comparison of the complete septic system interpretation from twenty-four field sites with the corresponding septic system interpretation from both Gallatin Valley and GNF soil surveys. Permeability results are based on nineteen observations.

Field data for bedrock is more comparable with GNF than Gallatin Valley data but values are lower, $p = 0.58$ vs. 0.42. Bedrock field data resulted in ten "severe", two "moderate", and twelve "slight" limitations. These results reflect the high variability of depth to bedrock within map units. Depth to bedrock at the Olson Creek and Bridger field sites varied from less than 1.0 m to more than 1.8 m. Shallow bedrock prohibited the collection of a soil sample for permeability analysis at five field sites; Olson Creek sites C and E, Hodgman Canyon sites D and E, and Bridger site E.

Field data results for permeability produced "severe" limitations for all soil pits. All but one "severe" permeability limitation was the result of slow percolation rates. Proportion values based on field permeability data showed better agreement with GNF data than Gallatin Valley data, $p = 0.74$ vs. $p = 0.63$. These results reflect two conditions; 1) the shallow depth to bedrock present along the border, and 2) the high number of soils with slow permeability restrictions. Field data also reflected the steep terrain along the border.

Field data results for slope produced eighteen "severe", two "moderate" and four "slight" slope limitations. Proportion values based on field results showed equal agreement with both surveys, $p = 0.63$. High variability within GNF slope classes that span multiple limitations may account for the low correlation based on GNF data. The data suggests that Gallatin Valley slope classes, used to determine slope limitations, are not site specific.

Field data for large stones did not show a strong correlation with either survey. However, the correlation with GNF data is stronger than with Gallatin Valley data, $p =$

0.42 and 0.25 respectively.

Summary

This study investigated the feasibility of obtaining septic system interpretations from a third order soil survey. The research focused on GNF soils along the Gallatin Valley/GNF border within the Gallatin LWQD. Users of this database should be cautious about extending results obtained along the border into other areas of Gallatin LWQD and especially into other areas of GNF. GNF map units within Gallatin LWQD represent eighty percent of the all GNF map units, however only thirty-five percent of GNF map units are represented along the Gallatin Valley/GNF border. Figure 18 illustrates the frequency distribution of the most limiting septic restriction for GNF soils in these three situations.

While results from this research show GNF soil survey data can provide information regarding septic system limitations of GNF soils, results also show the survey was not designed for septic system interpretations. This is most obvious in field data results for bedrock and slope. A survey designed for septic system interpretations will define map units that contain appropriate slope classes and bedrock information for septic system interpretation. Field data results for bedrock and slope exploited these deficiencies in the GNF database. This does not however, diminish the ability of the GNF soil survey to provide preliminary information regarding the septic limitations of GNF soils. Even the second order Gallatin Valley soil survey is not capable of providing site specific soil information.

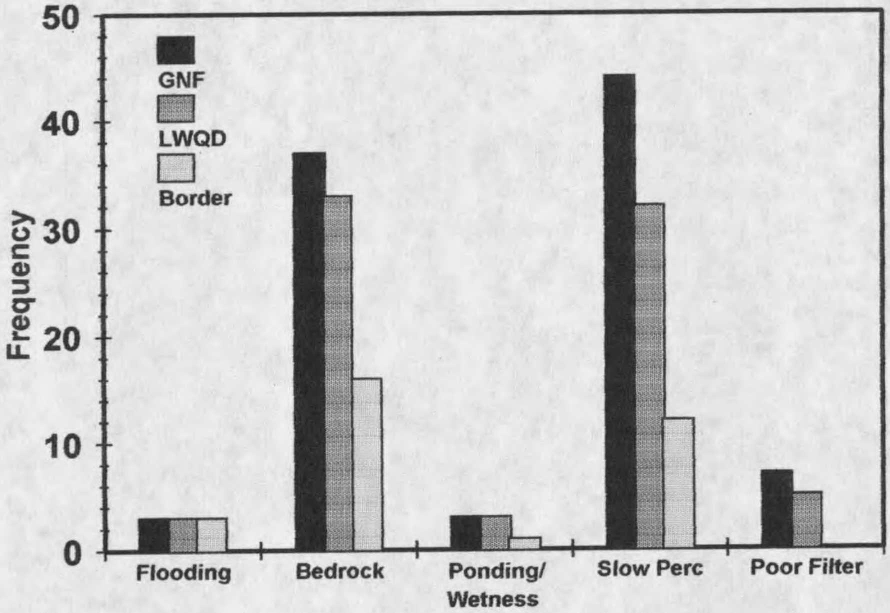

Figure 18. Frequency distribution of the most limiting septic interpretation for GNF map units; 1) within GNF, 2) within Gallatin LWQD and, 3) along the Gallatin Valley/GNF border.

> "While broad-scale planning and policy deliberations/decisions may appropriately be made by consulting a soil survey report, many intensive land uses may require collection of additional information through onsite investigations, possibly including highly detailed soil mapping, to improve precision in knowledge of soils in the landscape of concern. What are some examples of intensive land uses that might require onsite investigations of soils? Septic system siting would be one."

R. B. Brown, 1991.

CHAPTER 4

SOURCES OF ERROR

Database Errors

In order to make the comparisons in this study the Gallatin Valley soil survey was assumed to be "accurate." In actuality, all soil surveys contain errors due to the methods employed in making soil surveys (Powell and Springer, 1965; Beckett and Webster, 1971; Bie and Beckett, 1971; Amos and Whiteside, 1975; Schellentrager, 1990; Brown, 1991; Rogowski and Wolf, 1994;). Soil scientists directly examine less than one percent of the soil below the surface (Hudson, 1980; Hudson, 1990).

Each Gallatin Valley and GNF soil mapping unit is based on soil descriptions from other locations within the survey area. Descriptions of a typical pedon characterized in one area of the survey, along with the data used to make interpretations, are transferred to soils in other areas of the survey. "The assignment of a taxonomic name to a map unit merely means that we expect most locations within it to meet the criteria of that taxon," (Holmgren, 1988). The transfer of information from one location to another is a major source of inaccuracy in soil surveys (Nettleton et.al., 1991; Yost et. al., 1991; Rogowski and Wolf, 1994).

This study compared soils along the borders of both survey areas. Some

Gallatin Valley/GNF border map units may contain soils not described by the mapping unit. Typical pedons are generally described at interior locations away from survey borders. Soil series names may have been applied to soils with similar profile morphologies which occur on different landforms and/or parent material (Swanson, 1990). The pedons which border Gallatin Valley/GNF map unit properties are based, may not accurately represent the soils along the border. Additionally, map units are assumed to be pure bodies containing only the described soils. Research has shown some mapping units to be only fifty percent pure (Beckett and Webster, 1971).

Map unit boundaries in both surveys are assumed to define abrupt changes between homogenous soils (White, E. M. 1966.). Adjacent soils tend to be similar and boundaries between them indistinct and gradual (Wang, 1982; Hudson, 1990).

Measurement Error

Length figures used in the weighted average calculation were measured on a computer generated image with the use of the measurement tool within a software program. This assumes the process which produced the image is free of error. These images are generally digitized. Digitization is a multiple task manual process susceptible to mistakes.

CHAPTER 5

CONCLUSIONS

Results from this research show the third order GNF soil survey contains the data to provide septic interpretations of GNF soils within Gallatin LWQD. There is a seventy-five percent match of the septic interpretations between border Gallatin Valley/GNF soil map units. This suggests that septic interpretations from the third order GNF soil survey are comparable to septic interpretations from the second order Gallatin Valley soil survey.

GNF results for individual restrictions are highly variable and reflect a map unit design not intended for septic interpretations. Restrictions with high percent match values are dominated by "slight" limitation data. While these results may not indicate the ability of the third order GNF soil survey to accurately assess actual field conditions for these restrictions, the GNF soil survey equaled or exceeded results from the second order Gallatin Valley soil survey when tested under field conditions along the Gallatin Valley/GNF border.

GNF soil map units contain multiple "severe" restrictions for on-site sewage disposal. This compels the need for on-site investigations of proposed developments in rural areas of Gallatin LWQD. The purpose of every soil survey is to provide the most accurate information possible to the public. To this end we must be tenacious in our quest to update the database as information becomes available. This research extends the usefulness of the GNF soil survey and provides preliminary septic interpretations to Gallatin LWQD officials planning rural subdivisions. Weighted average calculations produced high agreement between border Gallatin Valley/GNF map units. These results suggest that the methodology may be transferrable to other regions in the Rocky Mountain West were urban sprawl necessitates the need for septic interpretations from third order soil surveys.

Further Research

The GNF soil survey includes portions of Gallatin, Madison, Meagher, Park, and Sweetgrass Counties. This provides the opportunity to test the methods and results used in this study in four other locations. Results from these future investigations will lend new insight into the validity of 1) the methods used in this investigation and 2) obtaining septic interpretations from a third order soil survey.

Another area of investigation could explore the feasibility of using Digital Elevation Models (DEM) to further refine the slope classes used in GNF map units. This may result in better agreement between border map units and also increase the confidence of the slope limitation data.

APPENDICES

APPENDIX A

SEPTIC LIMITATIONS FOR EACH GNF MAP UNIT WITHIN THE GALLATIN LWQD

* Map Unit	Restriction and Rating						
	Flooding	Bedrock	Ponding	Wetness	** Permeability	Slope	Large Stones
46-1B	slight	slight	none	slight	slow perc	moderate	severe
	slight	slight	none	slight	slow perc	moderate	moderate
54-1A	slight	severe	none	slight	poor filter	severe	severe
	slight	severe	none	slight	slow perc	severe	moderate
54-1B	slight	severe	none	slight	poor filter	severe	severe
	slight	severe	none	slight	poor filter	severe	moderate
54-1C	slight	severe	none	slight	poor filter	severe	severe
54-1G	slight	severe	none	slight	poor filter	severe	severe
54-2B	slight	severe	none	slight	slow perc	severe	severe
	slight	severe	none	slight	slow perc	severe	moderate
54-2C	slight	severe	none	slight	poor filter	severe	severe
54-2D	slight	severe	none	slight	slow perc	severe	severe
	slight	severe	none	slight	slow perc	moderate	severe
54-2E	slight	severe	none	slight	slow perc	severe	slight
	slight	severe	none	slight	poor filter	severe	severe
64-2A	severe	slight	none	slight	poor filter	moderate	moderate
	slight	slight	none	slight	slow perc	moderate	moderate
64-2C	severe	slight	none	slight	slow perc	moderate	severe
	slight	slight	none	slight	slow perc	moderate	severe
66-1A	severe	slight	severe	severe	slow perc	moderate	slight
	severe	slight	severe	severe	poor filter	moderate	slight

71-1A	slight	slight	severe	severe	slow perc	severe	slight
	slight	slight	none	slight	slow perc	severe	slight
71-1D	slight	slight	none	slight	slow perc	severe	moderate
	slight	slight	none	slight	poor filter	severe	severe
71-1E	slight	slight	none	slight	slow perc	severe	slight
	slight	slight	none	slight	slow perc	severe	slight
82-2B	slight	moderate	none	slight	slow perc	severe	slight
84-1A	slight	moderate	none	slight	slow perc	severe	slight
	slight	moderate	none	slight	slow perc	severe	slight
84-2B	slight	moderate	none	slight	slow perc	severe	moderate
	slight	moderate	none	slight	slow perc	severe	moderate
85-2A	slight	severe	none	slight	slow perc	severe	severe
	slight	severe	none	slight	slow perc	severe	severe
85-2B	slight	severe	none	slight	poor filter	severe	severe
	slight	severe	none	slight	slow perc	severe	moderate
85-3A	slight	moderate	none	slight	slow perc	severe	moderate
	slight	moderate	none	slight	slow perc	severe	moderate
85-3B	slight	moderate	none	slight	slow perc	severe	moderate
	slight	moderate	none	slight	slow perc	severe	moderate
86-2A	slight	severe	none	slight	slow perc	severe	slight
	slight	severe	none	slight	slow perc	severe	slight

86-2C	slight	moderate	none	slight	slow perc	severe	slight
86-2D	slight	moderate	none	slight	slow perc	severe	moderate
	slight	moderate	none	slight	slow perc	severe	moderate
86-3B	slight	moderate	none	slight	slow perc	severe	slight
	slight	moderate	none	slight	slow perc	severe	slight
86-3C	slight	moderate	none	slight	poor filter	severe	moderate
	slight	moderate	none	slight	poor filter	severe	slight
87-1B	slight	severe	none	slight	slow perc	severe	severe
	slight	severe	none	slight	slow perc	severe	severe
87-2A	slight	severe	none	slight	slow perc	severe	slight
	slight	severe	none	slight	slow perc	severe	slight
87-2B	slight	severe	none	slight	poor filter	severe	severe
	slight	severe	none	slight	slow perc	severe	slight
87-2C	slight	severe	none	slight	slow perc	severe	slight
	slight	severe	none	slight	slow perc	severe	moderate
87-2D	slight	severe	none	slight	slow perc	severe	moderate
	slight	severe	none	slight	slow perc	severe	moderate
91-2B	slight	moderate	none	slight	slow perc	severe	moderate
	slight	moderate	none	slight	slow perc	severe	moderate
93-1A	Rubble Land. Soil in less than ten percent of the map unit.						

* Most Abundant soil in the map unit listed first.

** Slow perc and poor filter signify “severe” permeability limitations.

APPENDIX B

SEPTIC RESTRICTIONS AND VALUES FOR EACH GNF MAP UNIT WITHIN THE GALLATIN LWQD

* Map Unit	Restriction and Value: Flooding	Depth to Bedrock (m)	Ponding (+/-)	Depth to Water (m)	Permeability (cm/hr)	Slope (%)	Large Stones (%)
46-1B	none	6.1	(-)	> 1.8	0.15	10.0	50.3
	none	6.1	(-)	> 1.8	0.15	10.0	39.0
54-1A	none	0.6	(-)	> 1.8	254.00	70	51.3
	none	0.6	(-)	> 1.8	254.00	70	47.9
54-1B	none	0.6	(-)	> 1.8	254.00	70	56.4
	none	0.6	(-)	> 1.8	254.00	70	39.8
54-1C	none	0.6	(-)	> 1.8	254.00	70	56.4
54-1G	none	0.6	(-)	> 1.8	254.00	70	56.4
54-2B	none	0.6	(-)	> 1.8	0.15	70	47.9
	none	0.6	(-)	> 1.8	0.51	70	52.4
54-2C	none	0.6	(-)	> 1.8	254.00	70	56.4
54-2D	none	0.6	(-)	> 1.8	0.15	70	50.3
	none	0.6	(-)	> 1.8	0.15	70	47.9
54-2E	none	0.6	(-)	> 1.8	0.15	70	17.0
	none	0.6	(-)	> 1.8	254.00	70	56.4
64-2A	occasional	7.6	(-)	> 1.8	254.00	10	39.4
	none	7.6	(-)	> 1.8	0.15	10	25.0
64-2C	occasional	7.6	(-)	> 1.8	0.51	10	46.5
	none	7.6	(-)	> 1.8	0.15	10	25.0

66-1A	frequent	7.6	(+)	0.6	0.15	10	4.5
	frequent	7.6	(+)	1.2	254.00	10	8.4
71-1A	none	7.6	(+)	0.3	0.15	20	11.3
	none	7.6	(-)	> 1.8	0.15	20	17.0
71-1D	none	7.6	(-)	> 1.8	0.51	20	46.5
	none	7.6	(-)	> 1.8	254.00	20	56.4
71-1E	none	7.6	(-)	> 1.8	0.15	20	0.0
	none	7.6	(-)	> 1.8	0.51	20	8.25
82-2B	none	1.5	(-)	> 1.8	0.15	20	17.0
84-1A	none	1.5	(-)	> 1.8	0.15	40	11.5
	none	1.5	(-)	> 1.8	0.51	45	8.3
84-2B	none	1.2	(-)	> 1.8	0.15	20	25.0
	none	1.2	(-)	> 1.8	0.15	20	40.0
85-2A	none	0.6	(-)	> 1.8	0.51	70	52
	none	0.6	(-)	> 1.8	0.15	70	48
85-2B	none	0.6	(-)	> 1.8	0.51	70	47
	none	0.6	(-)	> 1.8	254.00	70	56
85-3A	none	1.5	(-)	> 1.8	0.15	70	40
	none	1.5	(-)	> 1.8	0.15	70	25
85-3B	none	1.5	(-)	> 1.8	0.15	70	25
	none	1.5	(-)	> 1.8	0.15	70	40
86-2A	none	0.6	(-)	> 1.8	0.15	45	17
	none	0.6	(-)	> 1.8	0.15	45	0

86-2C	none	1.5	(-)	> 1.8	0.15	45	0
86-2D	none	1.5	(-)	> 1.8	0.15	45	40
	none	1.5	(-)	> 1.8	0.15	45	17
86-3B	none	1.5	(-)	> 1.8	0.51	30	8
	none	1.5	(-)	> 1.8	0.15	30	17
86-3C	none	1.5	(-)	> 1.8	254.00	45	40
	none	1.5	(-)	> 1.8	0.15	45	0
87-1B	none	0.6	(-)	> 1.8	0.51	70	52
	none	0.6	(-)	> 1.8	0.15	70	50
87-2A	none	0.6	(-)	> 1.8	0.51	70	8
	none	0.6	(-)	> 1.8	0.15	70	0
87-2B	none	0.6	(-)	> 1.8	0.15	70	17
	none	0.6	(-)	> 1.8	254.00	70	56
87-2C	none	0.6	(-)	> 1.8	0.15	70	0
	none	0.6	(-)	> 1.8	0.15	70	25
87-2D	none	0.6	(-)	> 1.8	0.51	70	47
	none	0.6	(-)	> 1.8	0.15	70	40
91-2B	none	1.5	(-)	> 1.8	0.15	45	25
	none	1.5	(-)	> 1.8	0.15	45	40
93-1A	Rubble Land. Soil in less than ten percent of the map unit.						

* Most abundant soil in the map unit listed first.

APPENDIX C

DESCRIPTION AND LOCATION

OF STUDY SITES

Four sites along the Gallatin Valley/GNF border provided data for this investigation. Stone Creek, Olson Creek and Bridger field sites are located northwest of Bozeman, Montana in the Bridger Canyon. Hodgman Canyon is located south-southwest of Bozeman, Montana in the Hyalite Mountain foothills. Soils in the second order Gallatin Valley survey are described at the series level of soil taxonomy. Soils in the third order GNF survey are described at the family, or higher, level of soil taxonomy.

Stone Creek

Stone Creek is located 15.3 km northeast of Bozeman, Montana. The Gallatin Valley/GNF border is approximately 0.6 km east of Bridger Canyon Road along GNF access road 480. Field sites were located south of the access road between the road and Stone Creek along the Gallatin Valley/GNF boundary in the NW1/4, NW1/4, SW1/4, Sec 10, T1S, R7E (Figure 19). Landforms include glacial outwash benches and terraces, alluvial fans, and floodplains. The site compares Gallatin Valley map unit 512D and GNF map unit 64-2A.

Major components of Gallatin Valley map unit 512D include fifty-five percent Enbar, twenty percent Bowery, and fifteen percent Nythar. Minor components include five percent Straw and five percent Blossburg soil series. Enbar soils are fine-loamy, mixed, superactive Cumulic Haploborolls. Bowery soils are fine-loamy, mixed, superactive Pachic Haploborolls. Nythar soils are fine-loamy, mixed, superactive frigid Cumulic Haploborolls.

GNF map unit 64-2A contains an undifferentiated group of forty-five percent loamy-skeletal, mixed Typic Cryoborolls, forty percent loamy-skeletal, mixed Argic Cryoborolls, and fifteen percent dissimilar soils.

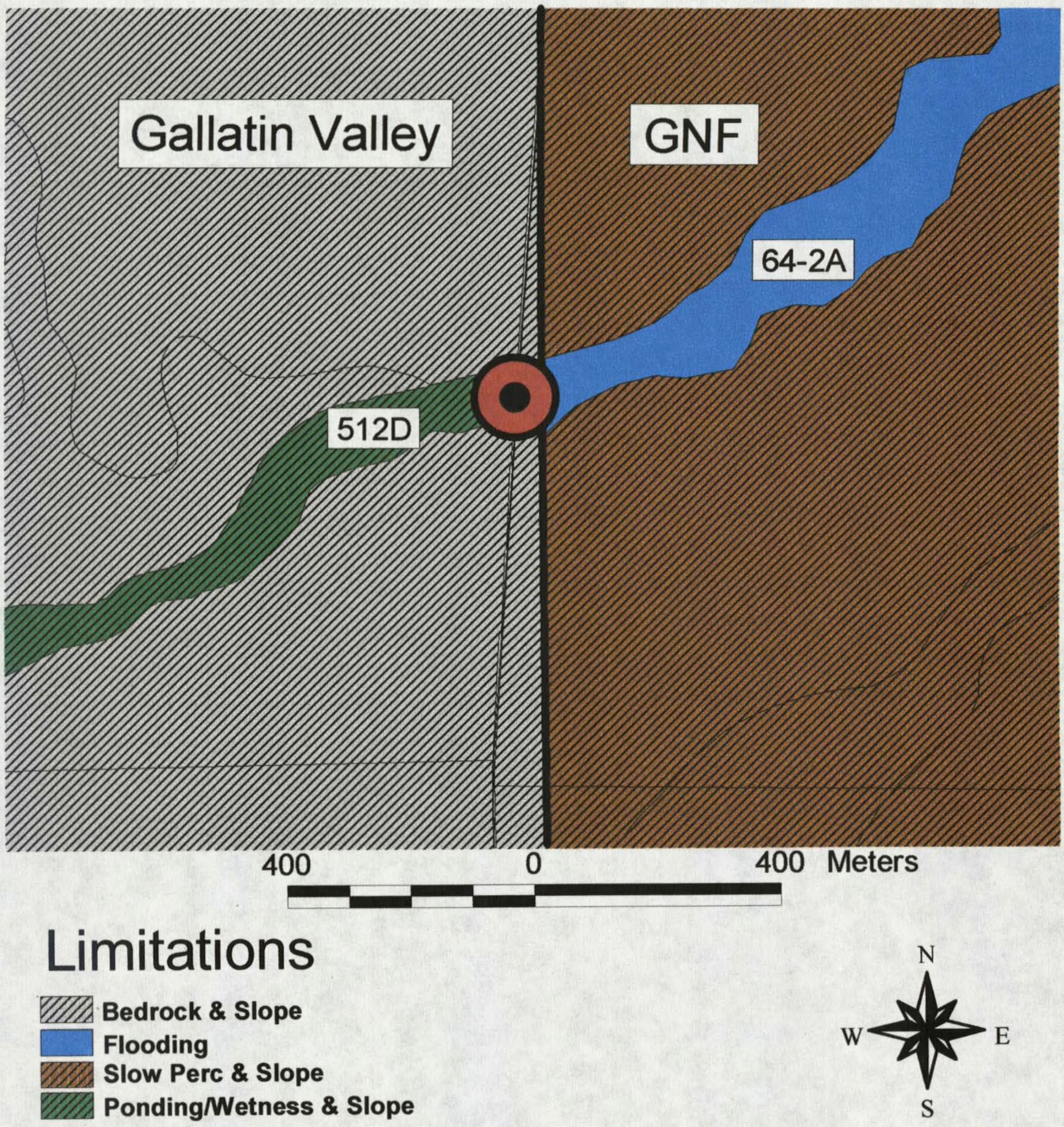

Figure 19. Location of Stone Creek field site along the Gallatin Valley/GNF border.

Olson Creek

Olson Creek is located 19.5 km northeast of Bozeman, Montana. The Gallatin Valley/GNF border is approximately 0.4 km east of Bridger Canyon Road along GNF access road 6944. The field site is located approximately 500 m north of GNF access road 6944 along the Gallatin Valley/GNF boundary in the NW1/4, SW1/4, SW1/4, Sec 28, T1N, R7E (Figure 20). Dominant slopes range from 45 to 70 percent. Landforms are bedrock controlled dip and scarp slopes. Ridges and swales are underlain by sandstone and shale respectively. The site compares Gallatin Valley map unit 647F and GNF map unit 85-3A.

Major components of Gallatin Valley map unit 647F include 40 percent Hoppers and similar soils, 25 percent Tolbert and similar soils, and 25 percent Timberlin and similar soils. Minor components include 5 percent Blaincreek stony loam and 5 percent rock outcrop. Hoppers soils are fine-loamy, mixed superactive Typic Argiborolls. Tolbert soils are loamy-skeletal, mixed superactive Lithic Argiborolls. Timberlin soils are loamy-skeletal, mixed superactive Mollic Cryoboralfs.

GNF map unit 85-3A is a complex of 35 percent loamy-skeletal, mixed Mollic Cryoboralfs, 35 percent loamy-skeletal, mixed Argic Cryoborolls, 20 percent rock outcrop and 10 percent dissimilar soils.

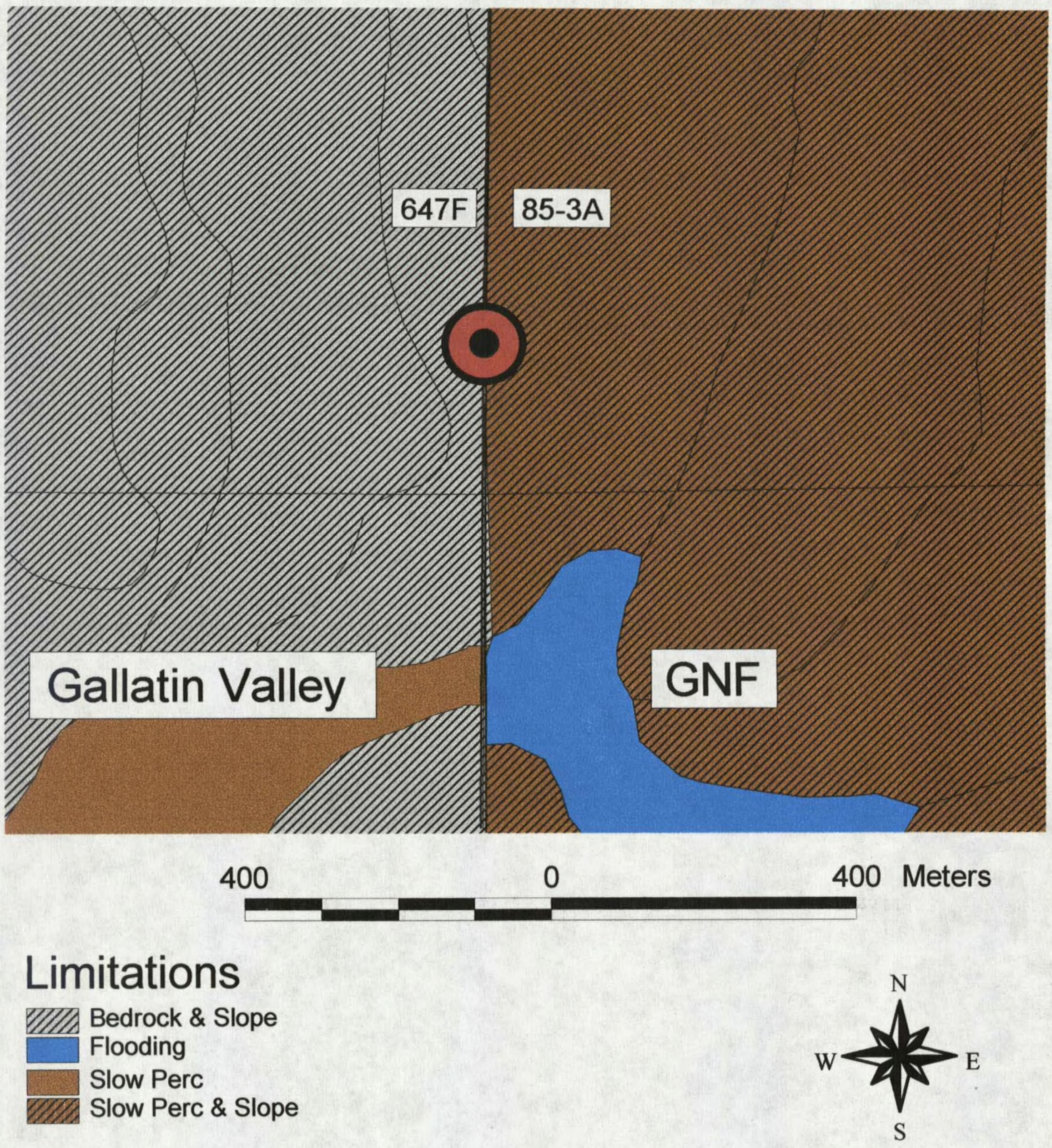

Figure 20. Location of Olson Creek field site along the Gallatin Valley/GNF border.

Bridger Creek

Bridger field site is located 23.6 km northeast of Bozeman, Montana. The Gallatin Valley/GNF border is approximately 500 m west of Bohart Ranch parking lot off Bridger Canyon Road. The field site is located approximately 500 m north of the Gallatin Valley/GNF border in the NE1/4, SE1/4, SE1/4, Sec.18, T1N, R7E (Figure 21). Dominant slopes range from 10 to 20 percent. Structurally controlled slopes follow the underlying bedrock. Slopes are wide at the base and thin towards the top. Landslide deposits are present in some drainage ways near seeps. The site compares Gallatin Valley map unit 294D and GNF map unit 84-2B.

Major components of Gallatin Valley map unit 294D include 65 percent Yellowmule, 20 percent Lonniebee, and 5 percent Redlodge and similar soils. Minor components include 5 percent Cowood channery sandy loam and 15 percent slopes greater than 15 percent. Yellowmule soils are fine, mixed, superactive Typic Cryoboralfs. Lonniebee soils are loamy-skeletal, mixed, superactive Typic Cryoborolls.

GNF map unit 84-2B is an association of 70 percent loamy-skeletal, mixed Mollic Cryoboralfs, 20 percent loamy-skeletal, mixed Argic Cryoborolls, 5 percent rock outcrop and 5 percent dissimilar soils.

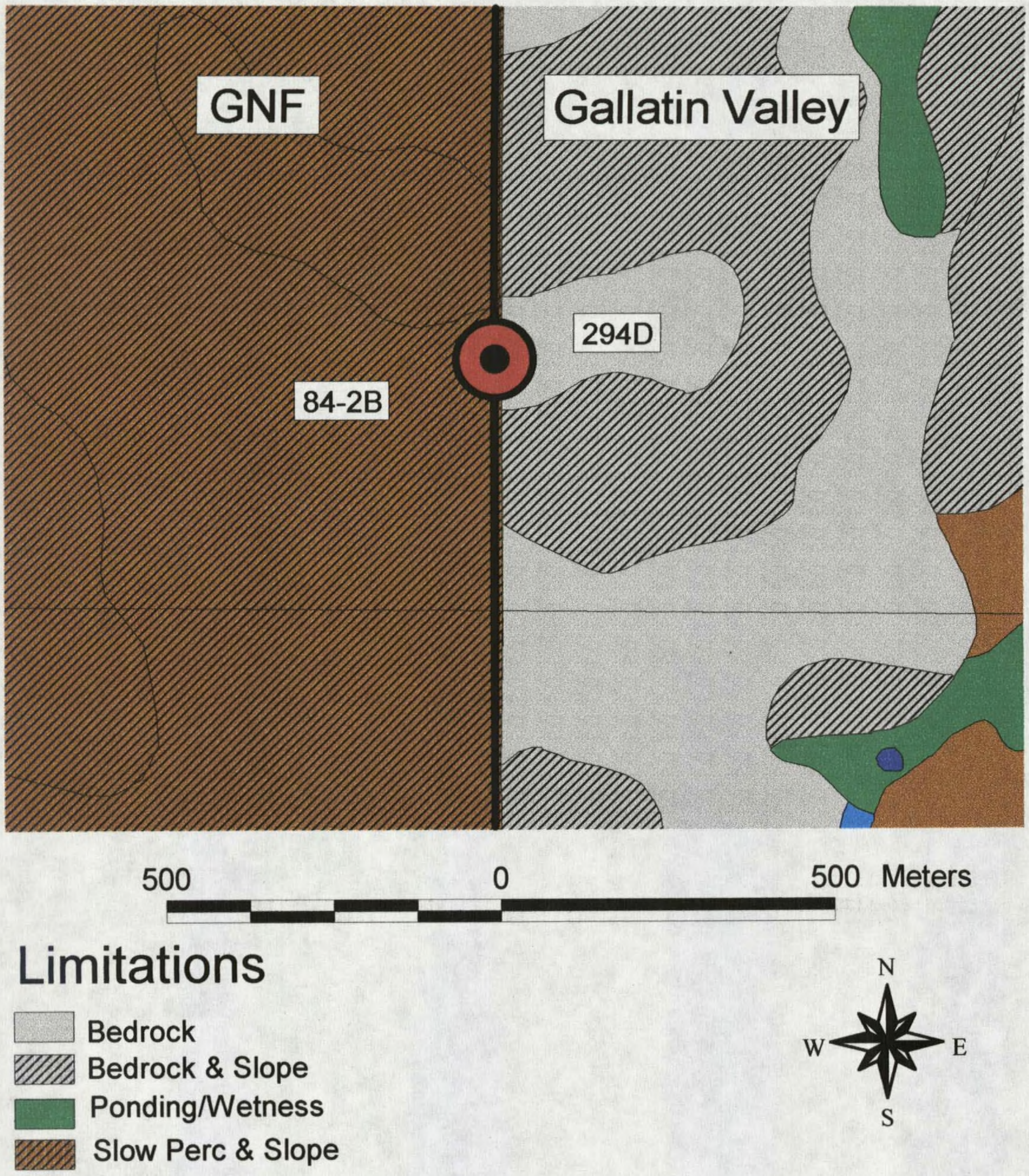

Figure 21. Location of Bridger field site along the Gallatin Valley/GNF border.

Hodgman Canyon

Hodgman Canyon field site is located 10.0 km southwest of Bozeman, Montana. The field site is located approximately 500 m west of the Hodgman Canyon trail along the Gallatin Valley/GNF border in the NW1/4, NE1/4, NE1/4, Sec. 14, T3S, R5E (Figure 22). Dominant slopes range from 45 to 75 percent. Mountain slopes are long, straight and may be slightly convex with streams at the base. The site compares Gallatin Valley map unit 382E and GNF map unit 54-1A.

Gallatin Valley map unit 382E is complex of 90 percent Bavdark soils and 10 percent dissimilar soils. Bavdark soils are fine, mixed, superactive Argic Pachic Cryoborolls.

GNF map unit 54-1A contains 45 percent loamy-skeletal, mixed Typic Haploborolls, 30 percent loamy-skeletal, mixed frigid Typic Ustochrepts, 20 percent rock outcrop and 5 percent dissimilar soils.

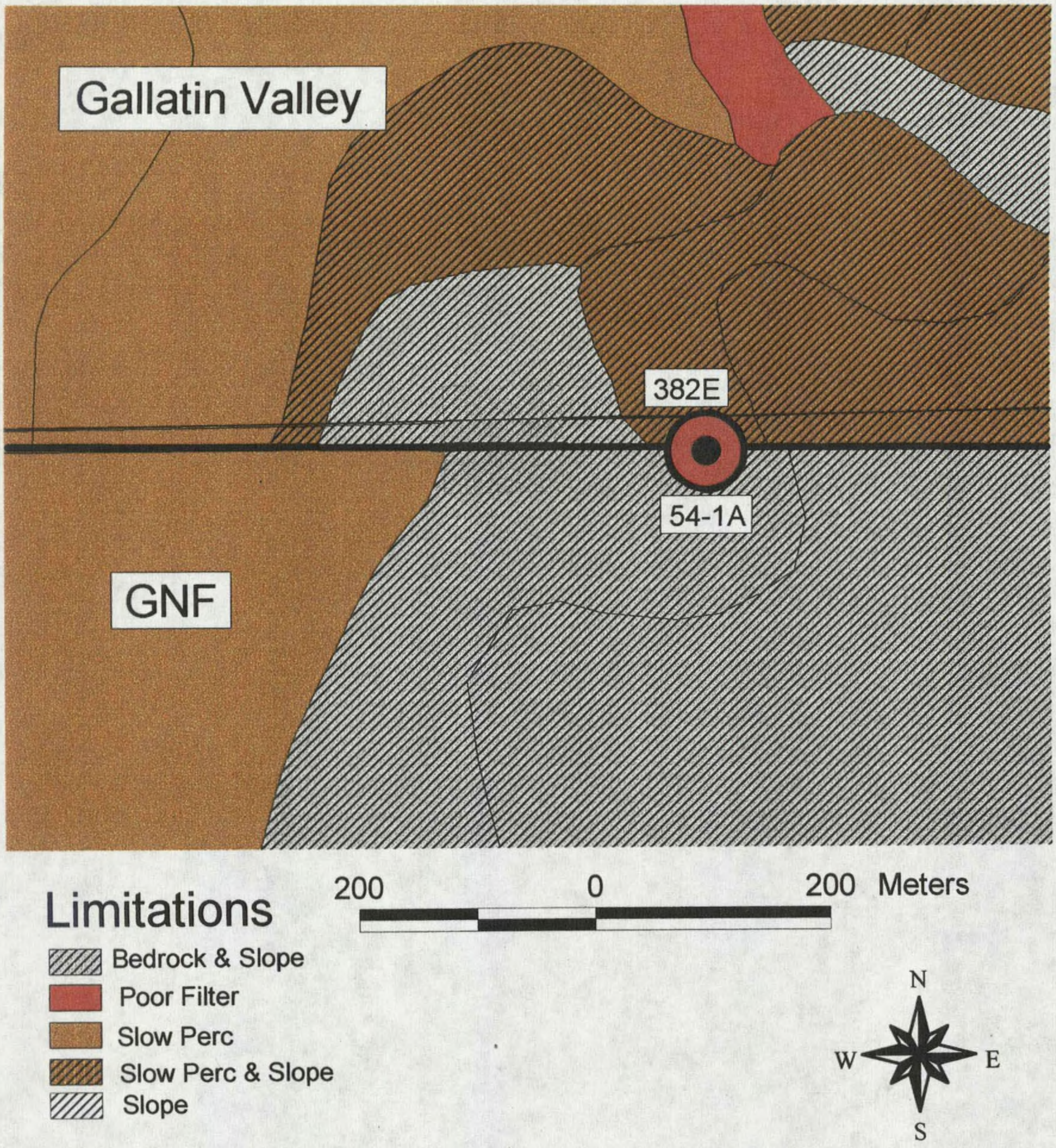

Figure 22. Location of Hodgman Canyon field site along the Gallatin Valley/GNF border.

APPENDIX D

SOIL PROPERTY, VALUE AND SEPTIC INTERPRETATION FOR STONE CREEK, OLSON CREEK, BRIDGER AND HODGMAN CANYON FIELD SITES

Stone Creek, GNF Sites						
Property	Pit A		Pit B		Pit C	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.51	severe	0.51	severe	0.51	severe
Percent Slope	27.0	severe	28.0	severe	35.0	severe
Percent Coarse Fragments	30.0	moderate	30.0	moderate	30.0	moderate

Stone Creek, Gallatin Valley Sites						
Property	Pit D		Pit E		Pit F	
	Value	Rating	Value	Rating	Value	Rating
Flooding	rare	moderate	rare	moderate	rare	moderate
Depth to Bedrock (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	0.46	severe	0.86	severe	0.61	severe
Permeability (cm/hr)	0.15	severe	0.15	severe	0.51	severe
Percent Slope	7.0	slight	7.0	slight	7.0	slight
Percent Coarse Fragments	55.0	severe	75.0	severe	75.0	severe

Olson Creek, GNF Sites						
Property	Pit A		Pit B		Pit C	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	1.42	moderate	1.02	severe	0.46	severe
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.51	severe	0.51	severe	no data	
Percent Slope	36.4	severe	35.0	severe	40.0	severe
Percent Coarse Fragments	30.0	moderate	30.0	moderate	36.0	moderate

Olson Creek, Gallatin Valley Sites						
Property	Pit D		Pit E		Pit F	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	1.6	moderate	0.38	severe	> 1.8	slight
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.51	severe	no data		0.15	severe
Percent Slope	28.0	severe	65.0	severe	51.0	severe
Percent Coarse Fragments	60.0	severe	85.0	severe	75.0	severe

Bridger, GNF Sites						
Property	Pit A		Pit B		Pit C	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.15	severe	0.15	severe	0.15	severe
Percent Slope	14.0	moderate	22.0	severe	14.0	moderate
Percent Coarse Fragments	8.0	slight	25.0	moderate	10.0	slight

Bridger, Gallatin Valley Sites						
Property	Pit D		Pit E		Pit F	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	> 1.8	slight	0.71	severe	> 1.8	slight
Depth to Cemented Pan (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.15	severe	no data		0.51	severe
Percent Slope	34.0	severe	17.6	severe	4.0	slight
Percent Coarse Fragments	8.0	slight	30.0	moderate	45.0	moderate

Hodgman Canyon, GNF Sites						
Property	Pit A		Pit B		Pit C	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	0.91	severe	0.74	severe	0.79	severe
Depth to Cemented Pan (m)	> 1.8	none	> 1.8	none	> 1.8	none
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	0.51	severe	0.51	severe	50.8	severe
Percent Slope	33.0	severe	21.0	severe	47.0	severe
Percent Coarse Fragments	30.0	moderate	10.0	slight	75.0	severe

Hodgman Canyon, Gallatin Valley Sites						
Property	Pit D		Pit E		Pit F	
	Value	Rating	Value	Rating	Value	Rating
Flooding	none	slight	none	slight	none	slight
Depth to Bedrock (m)	0.79	severe	0.41	severe	0.91	severe
Depth to Cemented Pan (m)	> 1.8	none	> 1.8	none	> 1.8	none
Ponding (+/-)	-	none	-	none	-	none
Depth to Water Table (m)	> 1.8	slight	> 1.8	slight	> 1.8	slight
Permeability (cm/hr)	no data		no data		0.51	severe
Percent Slope	33.0	severe	21.0	severe	47.0	severe
Percent Coarse Fragments	30.0	moderate	10.0	slight	75.0	severe

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