# The Greater Yellowstone Area
# Watershed Vulnerability Modeling Project

By

Henry F. Shovic, PhD and Wendi Urie, MS

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Interagency Spatial Analysis Center
Gallatin National Forest
U. S. Forest Service

Sponsored by the Greater Yellowstone Coordinating Committee and the Greater Yellowstone Area Hydrologists

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# OBJECTIVES AND STUDY AREA

On November 29, 2000 a multi-regional task force of hydrologists and soil scientists reviewed a variety of products from the Inland Water Ways Initiative (IWWI) relating to the Greater Yellowstone Area (GYA.) They examined six geographical products (Watershed Vulnerability, Watershed Geomorphic Integrity, Watershed Water Quality, Damaged Stream Segments, and Crucial Stream Segments.) Errors in these spatial data and their database attributes were generally found to be amenable to relatively minor editing. The exception is the Watershed Vulnerability data, which has major cross-administrative boundary differences, significant data gaps, and some major inconsistencies related to the quality and scale of data available at the time of ratings. Many of these ratings were made based on professional judgment and manual methods, and some of the rating individuals have since moved on.

Since these ratings were made, data quality and digital support methods have improved dramatically. The Interagency Spatial Analysis Center (ISAC) proposed to use these data, geographic information systems (GIS), and a modeling approach to build a model of watershed vulnerability for the entire GYA. Some specifications of this model follow:

- The most consistent system of rating vulnerability uses landtype-level data to aggregate sensitive lands to a watershed level. Landtypes or Ecological Land Units (ELU) in TEUI's (Terrestrial Ecological Unit Inventories) have the necessary information to provide the relevant criteria for the IWWI vulnerability layer. The model uses the "Landscape Model of the Greater Yellowstone" which includes digital, TEUI spatial and attribute data for 90 percent of all GYA administrative units. For those units where TEUI mapping is not complete or is at too broad a scale for this project, we will complete that mapping or model the relevant criteria.
- Criteria will include the "highly dissected" lands, not used in some earlier ratings.
- Watershed boundaries (HUC6) will be upgraded to currently available data. However, the model will be created for existing HUC6's also, since the other ratings maps are based on this earlier data, and we need to maintain consistency with these maps.

We proposed the project at the December meeting of the Greater Yellowstone Coordinating Committee, and accepted in February of 2001. It was funded in April of that year. This report shares results of the project. This report is in final draft form. Results were reviewed in December 2001 by the Greater Yellowstone Hydrologist Group. A final review will take place at their February 2002 meeting and the final report will be published at that time. Current data are available from the authors.

The Greater Yellowstone Area (GYA) can be defined in many different ways. For this study, we defined it as a block of federal land centered on Yellowstone National Park, with some included private lands that are surrounded by other federal lands (Figure 1.) Only federal and some included private lands are used because the data used in determining vulnerability is complete only for those lands and we want to be consistent with the earlier 1999 IWWI study.

To standardize the GYA for the study, we used a digital coverage (called GYAFS_BDY) of the area to define boundaries. We modified this from a 2000 coverage obtained from the Geometronics Service Center in Salt Lake City, which created it from Forest and National Park spatial data. The Extent (Table 1) and location (Figure 1) of GYA administrative units are based on this coverage.

These figures are approximate and may not be in complete agreement with more detailed work or with other coverages. However, they are of sufficient accuracy for this study. As in many large, complex studies using multiple data sources, figures given later in this study may vary from these totals. This is often because of small data and version differences, but may also be due to differences in definitions and sources of data. These differences are explained where they occur.

Some administrative units are only partially within the GYA. Not all area within these administrative units is included (Figure 1.) Only the Madison District of the Beaverhead-Deerlodge National Forest is used. For the Caribou-Targhee N. F., the non-contiguous portions of the Caribou National Forest are not used, as well as the lands west of IWWI watershed 170402150604 on the western extension of the Targhee National Forest. For the Custer N. F., only the Beartooth District is included.

Table 1. Land Area by Administrative Unit as used in this study

| Administrative Unit | Total Area (Acres)* |
|---|---|
| Beaverhead-Deerlodge N.F. | 750,581 |
| Bridger-Teton N.F. | 3,462,802 |
| Caribou-Targhee N.F. | 2,094,976 |
| Custer N.F. | 525,302 |
| Gallatin N.F. | 2,124,751 |
| Grand Teton N.P. | 333,139 |
| National Elk Refuge | 25,343 |
| Red Rock Wildlife Refuge | 58,811 |
| Shoshone N.F. | 2,466,963 |
| Yellowstone N.P. | 2,197,031 |
| Total Administrative Area | 14,039,699 |

* Unit areas are for the Greater Yellowstone Area only.

| | |
|---|---|
| Private lands within administrative coverage | 282,237 |
| Total Area from Administrative Coverage | 14,321,936 |

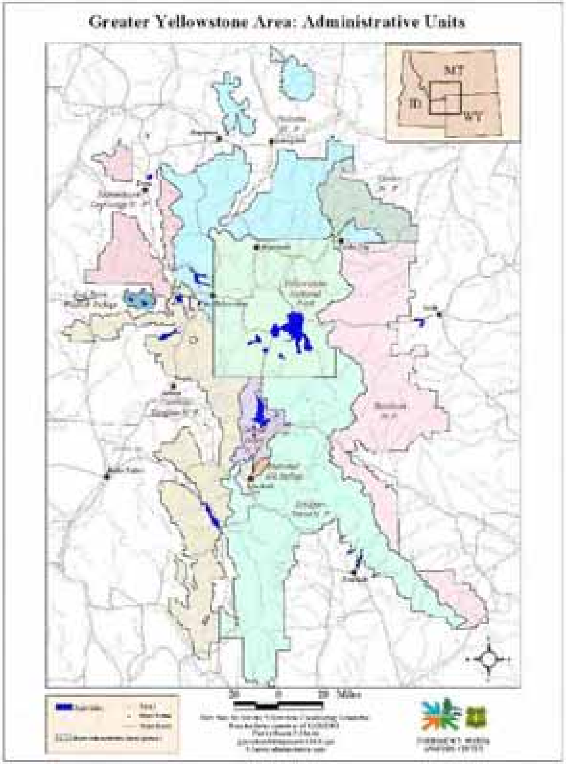



Figure 1. Greater Yellowstone Area: Administrative Units

# METHODS

## The IWWI Criteria and their Interpretation for This Model

Criteria given in Inland West Watershed Initiative (IWWI) literature are applied in this model for all lands in the GYA. One of our objectives is to develop a model to map these criteria uniformly across the entire area. Furthermore, all ratings are to be based on properties of the landscape, not interpretations of those properties. This will maximize consistency across management units, minimize subjective input on the part of project personnel, and allows re-mapping of the model as data and criteria change.

The following discussion is taken from an unpublished document provided by the IWWI Denver project team in 1999. This is titled "Inland West Watershed Reconnaissance." The term "watershed vulnerability" refers to the inherent risks of conditions becoming degraded if certain sensitive lands in a watershed are disturbed. This is not dependent on existing conditions, but only on the potential landscapes have for degradation. Ratings are based on the proportion of "sensitive lands" in a given watershed. This term refers to areas where disturbances pose a high probability of degrading watershed soil-hydrologic functions. Ratings include: Low = less than 20% of the watershed is in sensitive lands; Moderate= 20 to 50% are in sensitive lands; and High= more than 50% are in sensitive lands.

Lands must meet at least one of three criteria for designation as "sensitive." These criteria include "highly dissected" slopes, "highly-erodible soils", or "landslide deposits and potential landslides."

### Highly Dissected Slopes

Lands that are highly dissected have relatively dense stream networks. Their presence indicates running water has had a prominent role in landscape development. Any disturbance in these areas is likely to be close to a stream channel, increasing likelihood of sedimentation. The definition of "highly dissected" is open to discussion. In some circles it indicates slopes have deeply-incised drainageways. Some define it as a condition where all table or mountain lands have been dissected by streams, or other geomorphological process. Some refer to it as a condition where drainageways are closely spaced on steep slopes. Some specialists refer to areas where topographic maps indicate many crenulations, regardless of source. It can be interpreted as dissection frequency, depth of dissection, or a combination of these terms.

The objectives of this modeling effort include developing repeatable, quantitative measures applicable consistently over the entire GYA. Also, we want to emphasize the presence of stream channels without the additional interpretations needed for a classification of geomorphological process. Therefore we have defined "highly dissected" in terms of drainage density only, using a published guide (Haskins, et. al., 1998.)

Under Dissection Frequency Class, the following ratings are given.

- Un-dissected  (0 channels per mile)
- Slightly Dissected (1-3 channels/mile) (1760 – 5280 ft/drainage) or (537 – 1609 m/drainage)
- Moderately Dissected (3-10 channels/mile) (528 – 1760 ft/drainage) or 161 – 536 m/drainage)
- Highly Dissected (more than 10 channels/mile) (less than 528 ft/drainage) or less than 161 m/drainage)

The "highly dissected" frequency class is probably significant to hydrologic functioning at a watershed level. Using a digital representation of topography, we manually digitized these areas on-screen at a scale of 1:100,000, using a minimum map unit of 320 acres (129 ha.) This area was selected because it is relatively small compared to the average area of HUC6 watersheds, our summary unit, and is large enough to contain enough drainageways that we can determine drainage density. This level of detail is equivalent to the "Landscape" level in the National Hierarchical Framework of Ecological Units published by the Forest Service (ECOMAP, 1993.)

We consider fluvial dissection as the only process significant in increasing landscape sensitivity. Though dissection of landforms can relate to many landscape forming processes. Some of these are glaciation, mass-wasting, fault-controlled colluviation (slow, particle-based downhill movement), snow avalanche-scouring, or running water (fluviation). In the GYA, glaciation is the primary non-fluvial process involved in landscape dissection. This process left many apparently dissected areas that may or may not be sensitive today. Therefore glacial dissection was not used as mapping criteria.

Landscape sensitivity is sometimes related to climatic and geologic cycles not operating today. For example, some highly-dissected lands in relatively dry country were formed during post-glacial periods of high rainfall, and their character is "relict" from this time period. Little rainfall occurs today, so the landforms are relatively stable and lack sediment-transporting agents. We would prefer to differentiate this "relict" dissection from that which indicates sensitivity. To model this on a landscape basis, we would identify highly-dissected land areas that are in habitat types indicating relatively-dry current climatic conditions. These could be eliminated from further analysis. However, because "highly-dissected" is a relatively specific requirement in the IWWI criteria, we have not included this as differentiating. This will result in a probable over-estimation of "sensitive" lands using this criterion.

No existing inventories contain sufficient geomorphological description to be used for the delineation of highly-dissected lands as defined above. Criteria and terminology varied across surveys depending on their objectives and time-scale. No GYA-wide landform maps exist at the level of detail required for this project. Therefore we looked at ways of delineating an independent inventory of this single-factor characteristic.

Use of stream net development functions in GIS appears to work in small areas, but our trials indicate results are inconsistent over areas as large as a National Forest, which is small compared to the GYA. Though analysis of crenulations on contour maps shows promise for automating this process, there is no methodology developed that is usable on corporate equipment. Though the science of landform morphometry is advancing, only relatively simple measures oriented towards small areas have been developed. Because of the need for synthesis of many visual cues required in delineating dissection, manual delineation remained the only practical way to delineate these kinds of landforms.

We used GIS to make this process practical for the land area known as the GYA. Delineations were derived from interpreting a georeferenced "hillshade" image at a 30 m resolution. These hillshades are designed to shade the part of the topography facing away from an imagined "sun." A disadvantage of this orientation is that some of the topography is in "shade." To mitigate this problem, a high sun angle was used in the model, and two hillshades were used with opposite sun angles (Figure 2.) computed with an opposite sun orientation to obtain a complete picture of dissection. Excessive DEM errors (banding and data dropouts) occurred in the southern part of the study area. These problems were overcome by obtaining a more current DEM for that part of the study area.

The dissection criteria were applied to the contour, perpendicular to the longest dimension of a candidate landform. For mapping efficiency we determined that a 200 m drainageway density was more practical than the 161 m spacing specified above, and used that for the delineation criterion. Though visibility at the scale of mapping was the only criteria we used for strength of dissection, it is likely that only drainageways having more than about 100 meters of relative relief would be visible and measured in this study. The final coverage was created by digitizing on-screen as in ARC ™.

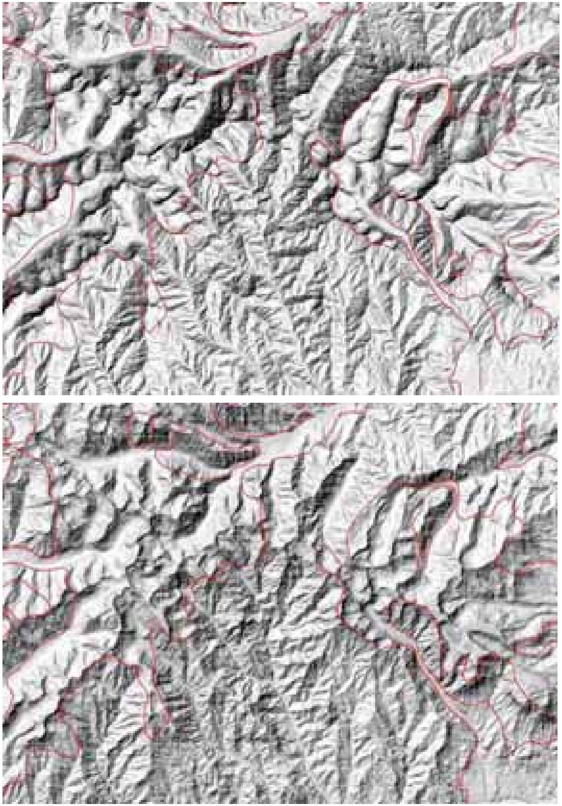


Figure 2. 1:100,000 scale view of hillshades and highly-dissected lands (upper is from sun azimuth of 135 deg and the lower is from an azimuth of 315 deg.)

**Highly-Erodible Soils**

Technically, "soil-erodibility" is an inherent property of the soil itself. Soil properties that affect infiltration, permeability, total water capacity, dispersion, splash, abrasion, and transport also affect erodibility. Actual "soil-erosion hazard" can be high or low with a given soil-erodibility, depending on slope, land cover, weather and climate conditions, landforms (including degree of dissection) and kind of disturbance (Kirkby and Morgan, ed., 1980.) For example, some soils on high-elevation tundra have high organic content, moderate textures, and a relatively low erodibility. However the high precipitation and short growing season mean that even with a relatively low erodibility, soils, will erode quickly if disturbed, and have a very long recovery period (Davis and Shovic, 1996.)

The example emphasizes that, with some exceptions, forested erosion and sedimentation events are significantly related to the environmental factors within which the soils exist, rather than solely from inherent properties of the soils themselves. This variability is an inherent weakness in using soil erodibility alone as an indicator of "sensitive" lands. However, since this is a relatively specific requirement in the IWWI document, we have used only soil properties to rate this factor. This will result in a probable under-estimation of "sensitive" lands using this criterion.

Properties affecting water erodibility include soil texture, organic matter content, size and stability of structural aggregates of the exposed layer, permeability of the subsoil, and depth to a slowly permeable layer. An approximation of an index of soil erodibility can be obtained by using soil texture (silt and very fine sand content, sand content), organic matter content, soil structure, and permeability (Kirkby and Morgan, ed., 1980.) Soils with high silt and very fine sand contents tend to have high erodibility factors, whereas sandy or clayey soils have rather low factors. Erodibility is also related to organic materials in the soil. Soils with high organic matter contents have somewhat lower factors than soils with low contents. Shallow soils are more erodible because of lower water-holding capacity and effective permeability.

These properties are mapped in different ways across the GYA in a variety of soil surveys and ecological unit inventories. The individual inventories have been integrated into one standardized spatial model, called the GYA Landscape Model (Shovic and Urie, 2001.) Though properties affecting soil erodibility are not directly mapped or described in this model, they can be inferred using the technical classification of soils, using Soil Taxonomy (USDA, 1999.) We used the soil classification to create a relative rating of erodibility at the landscape level, based on the above theory, standardized interpretive models (USDA, 1992, pp. 21-25; 1993, p. 297) and field experience in the GYA.

In taxonomic terms (USDA, 1999), any soils with a surface layer having a relatively high organic component with a significant base saturation (the Mollisol soil order, or a Mollic subgroups) are excluded from the highly-erodible class, unless shallow to bedrock (see below.) Soils with high silt and very fine sand contents tend to have the highest erosion potential. In terms of taxonomic description, this would include the "coarse-silty" and "fine-silty" particle size classes. Rock fragments significantly reduce the inherent erodibility of soils (Kral and Hawkins, ed. 1984.) Therefore, any soil Family having greater than 35 percent rock fragments is not considered highly-erodible. This would include all "skeletal" soil Families. All soils with bedrock close to the surface are susceptible to erosion ("Lithic" subgroups.) Soils with a significant component of volcanic ash tend to have high erodibility (the Andisol soil order.) Soils with a lesser amount are considered to be only moderately erodible (Andic subgroups.) Soils formed in hydrothermal materials are always considered highly-erodible. This is because of their unusual mineralogy and shallow depth class.

**Methods for Spatial Definition of Erodibility**

The existing GYA Landscape Model provided sufficient information on soil erodibility and landslides for most of the study area. However, there are some gaps where information was not available at the time of publication. We made efforts to provide complete coverage at the cost of lower resolution in some areas, and estimated properties through a consistent and repeatable process for others.

A VISUAL BASIC ™ program was written to make the criteria application process consistent, repeatable, and easily changed (Appendix One.) This program reads each of the 1,703 map unit records, determines if any major soil meets the erodibility criteria, and writes to another field if it does so. Soils information is searched from a summary field or in any of three major component fields. The presence of component information overrides a summary if it also exists, as we assume it is more detailed. A few map units lack soils information. These are flagged as well. The "highly-erodible" lands are represented as a field in the attribute table for the landscape model coverage.

A limitation of this method is that a map unit may be flagged for erodible soils even if only a small (though significant) part of that map unit actually has those soils. This may result in an overestimation of actual erodibility in a watershed. Since the model was predicated on use of landtypes as "atomic" objects (having a single property), this was not considered. However, because future model objectives may change, a modification was written for future use. If component proportions were present, the areal contribution each component having "highly-erodible" soils was weighted by its component proportion. For example, if Soil Component One was 30 percent of the map unit, and was in the erodible class, the proportion of erodible soils was that proportion. However, if Component Two was also "highly-erodible", and had a proportion of 20%, the total in the map unit would be 50%. Up to 15 % of any one map unit can be "dissimilar inclusions". These were not included in this analysis, so no cumulative proportion will add to 100%, unless generated from a soil summary field. For map units having only soil summary information, each criterion rule that fires raises the cumulative proportion by 33% to a maximum of 99%. This approximates the contribution of more than one erodible soil in the summary.

**Landslides**

Presence of landslides and potential for landslides are both used as criteria for unstable slopes. Existing landslides may indicate a pre-disposition towards additional slope failures when disturbed. The presence of landslides on the landscape is relatively easily mapped as they have distinct visible characteristics, and are listed as properties of map units in GYA inventories. The potential for landslides, however, is more difficult to define, because it is an interpretation based on those properties. Because it is an interpretation, and criteria for those interpretations are not contained in the GYA landscape model, potential for landslides is not mapped in this model. This probably results in an under-estimation of "sensitive" lands using this criterion.

Spatial definition of landslides was relatively straightforward. Massive earth movements ("landslides") are described and classified in a number of relatively standard ways (e. g. Thornbury, 1969; Haskins, et. al., 1998.) Therefore, after a review of the database terms in the GYA model, a search query was created to find map unit records having terms relating to potential mass movement. These terms include "landslide", "mass wasting", "earthflow", "slumps", "rock slides", and "block glide", or words using these terms, present in any of nine fields in the database. See query # 54 (landslides filter for later manual selection) in Appendix Two. Once these were selected, each map unit record was manually examined to determine if mass movement was a dominant component of the map unit. If landslides made up more than a "small" or "included" part of the unit, the unit was flagged as a landslide. Landslides are represented as a field in the attribute table for the landscape model coverage.

## The Landscape Model Used in the Vulnerability Analysis

### The Landscape Model and Data Additions for this Project

The 2000 GYA Landscape Model (Shovic and Urie, 2001) is a systematic compilation and integration of ecotype, landtype, and soils survey information for the entire Greater Yellowstone area. It contains a single spatial coverage and a single linked database having standardized language, field descriptions, and a level of quality control. Information on vegetation, landforms, soils, geologic features, and climate can be extracted from this model. As published, it contains only those landscape data that were completed and published before 2000. Some gaps remained in the GYA. Since then more data have become available in draft form. The quality of these additional data was sufficient for inclusion in this model, so the following additions were made. See Figure 3 for a map of the 2000 data and the modified data used in this project. See Figure 1 for each administrative unit's location.

Bridger Teton National Forest: All existing inventory areas were of sufficient detail for this project save those in the Teton and Gros Ventre Wilderness Areas. These were older, reconnaissance surveys and are at a much lower resolution than the remainder of inventories in the GYA. They were used here due to lack of better information. Some ratings on the Bridger-Teton National Forest were potentially inaccurate. Landscape data were very broadly defined in the northern portion of the Forest. This probably resulted in an under-assessment of vulnerability in this area. There also may be some missing landslide data in the map units representing the Flat Creek area south of the wilderness. Vulnerability ratings may be higher than shown here.

Custer National Forest: The Custer portion of the Absaroka-Beartooth Wilderness Area is now in process of being inventoried. About 1/3 of the area has a draft inventory of sufficient resolution to be used in this exercise. Though detailed soil information was absent, erodibility and landslide occurrence were estimated from aerial photography, existing adjoining information, and the hillshade image.

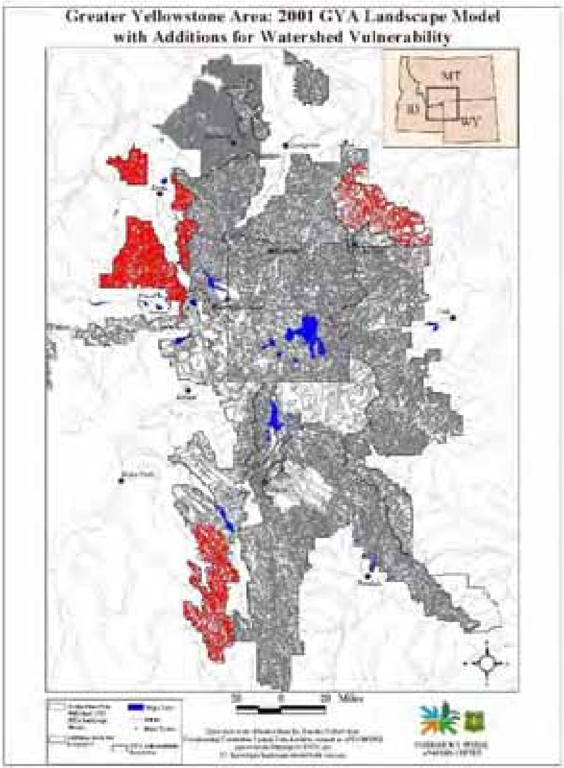



Figure 3. Greater Yellowstone Area: 2001 GYA Landscape Model with Additions for Watershed Vulnerability

Most of the criteria for erodible soils are not likely to apply to the heavily glaciated, rocky remainder of the area. However, it is likely there will be shallow soils having high erodibility on steep, glaciated slopes. Therefore a reconnaissance inventory was completed on this area using the hillshade image and surrounding mapping at a scale of 1:100,000. This identified landslides and highly-erodible soils by landform, slope gradient, and slope shape.

Caribou National Forest (part of the Caribou-Targhee National Forest): Though digital spatial information is available, tabular attributes are not in an easily imported form. For this project, the spatial information was appended to the existing model, and appropriate attribute information was manually entered.

Beaverhead National Forest (Madison District, part of the Beaverhead-Deerlodge National Forest: This inventory is in the final stages of completion. Draft spatial information was edge-matched and appended to the model. Draft digital attribute information was obtained and was formatted for this model. This information may change somewhat for the final publication, but is considered sufficient for the present study.

Gallatin National Forest: The term "lithic" was not used in the soil definitions used in the present version of the digital database. However, shallow soils were described for map units in the accompanying publication, and were manually entered. Six map units were missing soils information. Soil components for these map units were projected from surrounding map unit information.

Yellowstone National Park: No adjustments were made.

Grand Teton National Park: No adjustments were made.

Shoshone National Forest: No adjustments were made.

Red Rocks National Wildlife Refuge: This administrative unit, though in the Greater Yellowstone Area, was not analyzed. No soils information was available.

National Elk Refuge: This area was analyzed, because soils and landslide information was available through the Grand Teton National Park and Teton County inventories.

**Data Completeness**

Two kinds of data are flagged as "no data" in our project. The first kind includes mapped lakes and large streams in the Landscape Model. These have no soil or landslide data but do have validity for calculations within watersheds. The second includes existing landscape map units lacking attribute data or areas within the project boundary having no spatial data. This category represents a true "no data" status in this project. Excluding lakes and streams, soil erodibility and landslides data coverage for the GYA was nearly complete, with only four percent of the entire area missing data (Table 2.) Figure 4 shows the distribution of this missing data. The southeast portion of the Shoshone National Forest, though inventoried, has no digital spatial data (about 248,000 acres; "G" on Figure 4.) Another 97,688 acres has spatial data but no attribute data ("F" on Figure 4.)

Table 2. Lands with No Soils Data in The GYA (excluding lakes and streams)

| Administrative Unit | No Landscape Data (Acres) | Total Unit Area (Acres)* | Percentage of Total Area*** | Comments |
|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 161,323 | 750,581 | 21.5% | Landscape data missing in North Madison Range |
| Bridger-Teton N.F. | 17,166 | 3,462,802 | 0.5% | Landscape data missing south of Jackson |
| Caribou-Targhee N.F. | 1,522 | 2,094,976 | 0.1% | |
| Custer N.F. | - | 525,302 | 0.0% | |
| Gallatin N.F. | - | 2,124,751 | 0.0% | |
| Grand Teton N.P.** | - | 333,139 | 0.0% | |
| National Elk Refuge | - | 25,343 | 0.0% | |
| Red Rock Wildlife Refuge | 58,811 | 58,811 | 100.0% | No landscape data |
| Shoshone N.F. @ | 345,668 | 2,466,963 | 14.0% | Landscape data missing in SE |
| Yellowstone N.P. | - | 2,197,031 | 0.0% | |
| Totals | 584,490 | 14,039,699 | 4.2% | |

* Unit areas are for the Greater Yellowstone Area only.

** Includes John D. Rockefeller Parkway

*** Figures do not include 75,996 acres with no landscape data on private lands within Unit boundaries.

@ Includes about 248,000 acres of missing spatial data, with the remainder having spatial data but no attribute data.

A part of the Beaverhead-Deerlodge National Forest (161,323 acres) was missing attribute data. This missing data is concentrated in the northeast part (“B” on Figure 4), but some are scattered throughout the area. The area just south of Jackson was missing attribute data (17,166 acres; “E” from Figure 4) though spatial data were present. The Red Rock Wildlife Refuge has no landscape data (58,811 acres; “H” on Figure 4). This is because it is has been added to the GYA in the last year, too late for inclusion in the landscape model.

Large blocks of non-federal land within GYA boundaries have no landscape data (“C” and “D”) and are not included in the missing data analysis (see Table 1.) However, smaller, un-mapped areas make up 75,996 acres of missing data. These are scattered throughout the GYA and are not excluded from analysis. Spatial and attribute data from one large block of private land outside of GYA boundaries (but inside the landscape model boundaries) was excluded by query (“A” on Figure 4.) Another area just south of Jackson is private, but was included in the landscape model.

Some ratings on the Bridger-Teton National Forest were potentially inaccurate. Landscape data were very broadly defined in the northern portion of the Forest. This probably resulted in an under-assessment of vulnerability in this area. There also may be some missing landslide data in the map units representing the Flat Creek area south of the wilderness. Vulnerability ratings may be higher than shown here.

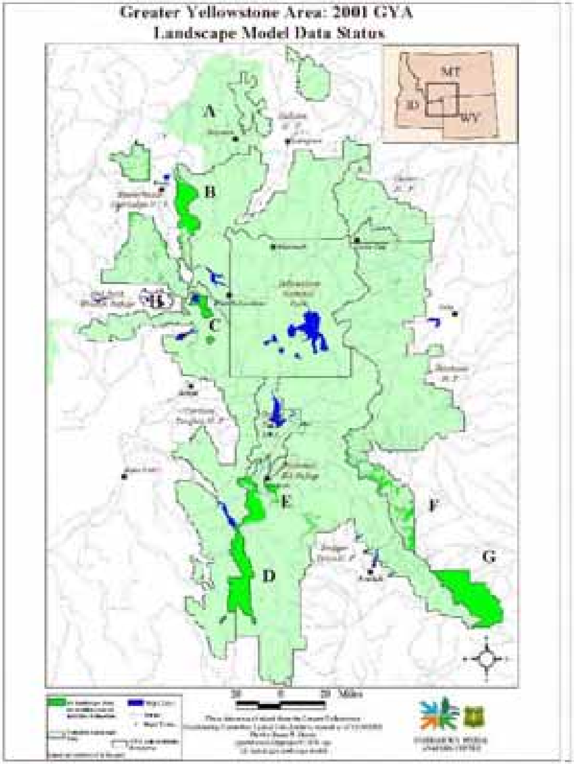



Figure 4. Greater Yellowstone Area: 2001 GYA Landscape Model Data Status.

# Watershed Data

### IWWI Watershed Data and GYA Watershed Data

Two watershed coverages were used in this study, each one providing a base from which rate vulnerability by watershed using the landscape model. The first (Figure 5) is from the IWWI project (termed IWWI Watersheds) completed using data gathered in 1999. This was compiled at the 6th Hydrologic Unit Code level, and is commonly called the HUC6 watershed layer. This was used as the spatial base for the first part of the study, that of delineating watershed vulnerability with the "sensitive" lands coverage from the landscape model. There are areas of missing data, notably in Grand Teton National Park and the surrounding area. Also, administrative boundaries define watersheds, notably around Yellowstone National Park.

The IWWI data were provided in a series of coverages, one for each administrative unit. We did not have the resources to append and edgematch all of them, so our analysis was completed by individual units and totaled for the GYA. With this in mind, we calculated there are about 1,130 total watersheds in the IWWI coverages with a total area of about 13,500,000 acres and an average size of about 13,000 acres. Note that watersheds are clipped at unit boundaries, resulting in an under-reporting of average size. Also, we intersected these coverages with the landscape model, resulting in somewhat lower numbers of reported watersheds and areal extent.

We compiled the second coverage (termed GYA Watersheds) from watershed data developed in 2001 by federal and state administrative units. We appended and edgematched these data, and used only that data within the GYA administrative unit coverage (Figure 6.) There are some data gaps, notably in the western part of the Caribou-Targhee National Forest. This is because data were in process of completion and not ready at time of publication.

We used this second coverage in the second part of the study, delineating watershed vulnerability with the new "sensitive" lands coverage from the same landscape model used above. There are about 765 total watersheds in the GYA watershed coverage (within the GYA boundary) with a total area of about 12,600,000 acres and an average size of about 16,800 acres. Again, we intersected this coverage with the landscape model, resulting in relative under-reporting of these figures later in the analysis.

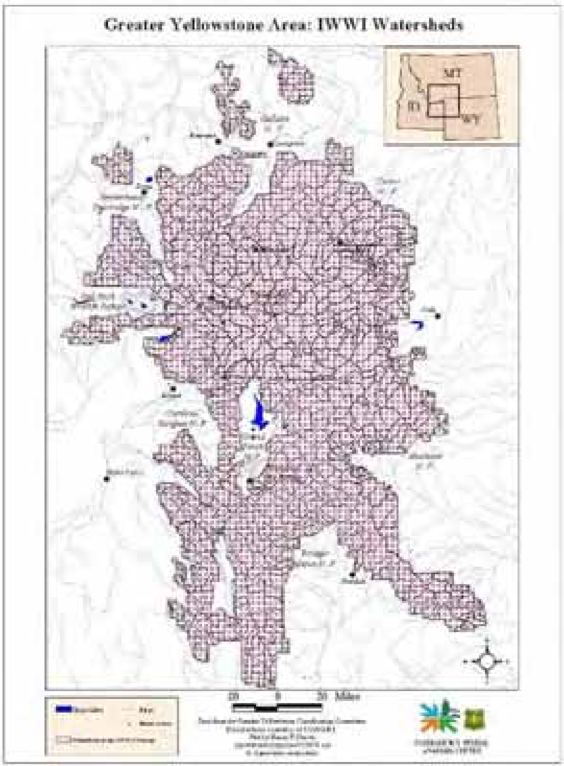



Figure 5. Greater Yellowstone Area: IWWI Watersheds

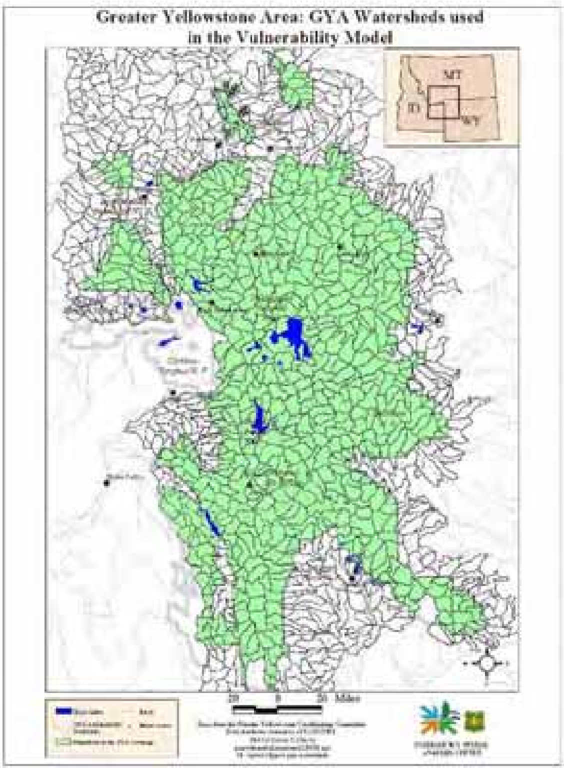



Figure 6. Greater Yellowstone Area: GYA Watersheds used in the Vulnerability Mode

**Comparison of The Two Watershed Coverages**

There are advantages in using the newer watershed coverage. The GYA coverage is considerably updated in terms of individual delineations (Figure 7.) Note that delineations are apparently more detailed. Watersheds have been corrected within units ("D" vs. "C"). Cross-boundary joins have been improved ("E" vs. "F".) Data holes ("A") and boundaries based soley on administrative units ("B") have been removed. Finally, watersheds for Grand Teton National Park and the National Elk Refuge have been added.

However, there are some disadvantages. Overall completeness for the GYA coverage is 5.6 percent less than that for the IWWI coverage (Table 3), primarily due to lack of data for the western portion of the Caribou-Targhee National Forest (Figure 6.) The data in Table 3 are taken from Table 4 and Table 5. These tables show the missing watershed data compiled by administrative unit. Areal extent for both coverages has been modified by those reductions related to absence of watershed data only, and not for the landscape model.

Table 3. Area Covered by IWWI HUC6 and GYA HUC6 Watersheds

| Administrative Unit | IWWI Watershed Coverage (Acres) * | GYA Watershed Coverage (Acres)* | Difference in Coverage (Acres) | Percentage Difference in Coverage |
|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 749,581 | 750,466 | 885 | 0.1% |
| Bridger-Teton N.F. | 3,459,073 | 3,325,482 | (133,592) | -3.9% |
| Caribou-Targhee N.F. | 2,094,976 | 1,124,442 | (970,534) | -46.3% |
| Custer N.F. | 524,633 | 525,302 | 669 | 0.1% |
| Gallatin N.F. | 2,116,407 | 2,124,485 | 8,079 | 0.4% |
| Grand Teton N.P.** | - | 333,122 | 333,122 | 100.0% |
| National Elk Refuge | - | 25,343 | 25,343 | 100.0% |
| Red Rock Wildlife Refuge | - | (0) | (0) | 0.0% |
| Shoshone N.F. | 2,465,963 | 2,466,951 | 988 | 0.0% |
| Yellowstone N.P. | 2,181,108 | 2,155,581 | (25,527) | -1.2% |
| Totals without Private Lands | 13,591,742 | 12,831,174 | (760,568) | -5.6% |
| Private Lands within coverage | 233,685 | 282,237 | | |
| Totals with Private Lands | 13,591,742 | 13,113,411 | (478,331) | -3.5% |

* These data are taken from Table 4 and Table 5. Areal extent for both coverages has been modified by those reductions related to absence of watershed data only, and not for the landscape model.

Table 4. Land Area by Administrative Unit as used for the Vulnerability Model with GYA Watershed Data

| Administrative Unit | Total Area (Acres)* | Area Missing Watershed Data | Actual IWWI Watershed Area (Acres) | Percentage with Missing Data | Reason for "Missing Data" Designation |
|---|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 750,581 | 115 | 750,466 | 0.0% | no GYA watershed data |
| Bridger-Teton N.F. | 3,462,802 | 137,320 | 3,325,482 | 4.0% | no GYA watershed data |
| Caribou-Targhee N.F. | 2,094,976 | 970,534 | 1,124,442 | 46.3% | no GYA watershed data |
| Custer N.F. | 525,302 | | 525,302 | 0.0% | |

| | | | | | |
|---|---|---|---|---|---|
| | | (0) | | | |
| Gallatin N.F. | 2,124,751 | 266 | 2,124,485 | 0.0% | no GYA watershed data |
| Grand Teton N.P. | 333,139 | 17 | 333,122 | 0.0% | no GYA watershed data |
| National Elk Refuge | 25,343 | (0) | 25,343 | 0.0% | |
| Red Rock Wildlife Refuge | 58,811 | 58,811 | (0) | 100.0% | no GYA watershed data |
| Shoshone N.F. | 2,466,963 | 12 | 2,466,951 | 0.0% | no GYA watershed data |
| Yellowstone N.P. | 2,197,031 | 41,450 | 2,155,581 | 1.9% | no GYA watershed data |
| Total Administrative Area | 14,039,699 | 1,208,525 | 12,831,174 | 8.6% | |
| Private lands within administrative coverage | 282,237 | | | | |
| Total Area from Administrative Coverage | 14,321,936 | | | | |

* Unit areas are for the Greater Yellowstone Area only.

Table 5. Land Area by Administrative Unit as used for the Vulnerability Model with IWWI Watershed Data

| Administrative Unit | Total Area (Acres)* | Area Missing Watershed Data | Actual IWWI Watershed Area (Acres) | Percentage with Missing Data | Reason for "Missing Data" Designation |
|---|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 750,581 | 1,000 | 749,581 | 0.1% | Edgematch artifacts |
| Bridger-Teton N.F. | 3,462,802 | 3,729 | 3,459,073 | 0.1% | Edgematch artifacts |
| Caribou-Targhee N.F. | 2,094,976 | - | 2,094,976 | 0.0% | |
| Custer N.F. | 525,302 | 669 | 524,633 | 0.1% | Edgematch artifacts |
| Gallatin N.F. | 2,124,751 | 8,344 | 2,116,407 | 0.4% | Edgematch artifacts |
| Grand Teton N.P. | 333,139 | 333,139 | - | 100.0% | No IWWI Watershed Data |
| National Elk Refuge | 25,343 | 25,343 | - | 100.0% | No IWWI Watershed Data |
| Red Rock Wildlife Refuge | 58,811 | 58,811 | - | 100.0% | Outside IWWI Watershed Data |
| Shoshone N.F. | 2,466,963 | 1,000 | 2,465,963 | 0.0% | Edgematch artifacts |
| Yellowstone N.P. | 2,197,031 | 15,923 | 2,181,108 | 0.7% | No IWWI Watershed Data, on the W edge of park |
| Total Administrative Area | 14,039,699 | 447,957 | 13,591,742 | 3.2% | |

* Unit areas are for the Greater Yellowstone Area only.

| | |
|---|---|
| Private lands within administrative coverage | 233,685 |
| Total Area from Administrative Coverage | 14,273,383 |

NOTE: These figures are from data queries and estimation.

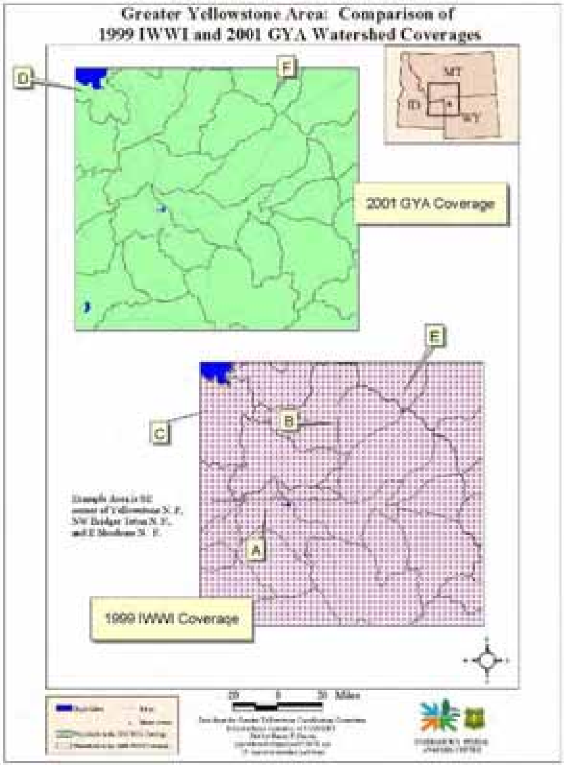



Figure 7. Greater Yellowstone Area: Comparison of 1999 IWWI and 2001 GYA Watershed Coverages

# RESULTS

## Calculations for Dissected Lands, Highly-Erodible Lands, Landslides, and Sensitive Lands in the GYA

Highly-erodible and landslide-prone areas are represented as attributes of polygons in the landscape model coverage. Dissected lands are a separate coverage. These two coverages were intersected to form a coverage having both attributes. The resulting attribute table was imported to ACCESS ™ where we used a series of queries to clean the data, calculate areas for the three parameters, remove overlap, create a table of final attributes, and summarize for the tables given below (Table 6.) This series of queries are standardized, so when data changes it is convenient to redo these tables.

Table 6. Query List for Unit Calculations

| Query | Record Source (Table or Query) | Query Number* | Records |
|---|---|---|---|
| Create attribute table from relations | table | 37 | 59,955 |
| Select Valid Records from Attribute table | table | 42 | 46,956 |
| Initialize Sensitive Area Fields | table | 43 | 59,955 |
| Assigns Area based on Erodibility | 42 | 44 | 7,704 |
| Assigns Area based on Landslides and Dissection | 42 | 45 | 9,649 |
| Assigns No Data for Erodibility and Landslides | 42 | 46 | 8,500 |
| Re-assign sensitivity if dissected lands and no landscape data | 42 | 47 | 7,050 |
| Summarize Sensitivity (Vulnerability) by Unit (Table 10) | 42 | 10 | 11 |
| Summarize Dissection by Unit (Table 7) | 42 | 33 | 10 |
| Summarize Landslides by Unit (Table 9) | 42 | 15 | 10 |
| Summarize Erodible Soils by Unit (Table 8) | 42 | 13 | 10 |

* Query descriptions and SQL are in Appendix Two.

### Highly Dissected Lands

We delineated highly-dissected lands using the criteria listed above for the entire GYA defined above in Figure 1. Though we delineated lands on all Federal and most private lands, we excluded two large areas ("C" and "D" in Figure 4.)

One of the least dissected areas is Grand Teton National Park (Table 7.) Though from outward appearances this park is dominated by steep, rugged terrain, almost all of the mountainous area does not meet the criteria for "highly-dissected" land in terms of drainage density. This is probably due to relatively hard bedrock, recent uplift, and strong glaciation.

Most dissected lands occur in the Shoshone National Forest and the southern part of the Caribou-Targhee National Forest (Figure 8.) The Shoshone National Forest has large areas of relatively erodible volcanic rock, landscapes of greater age, and less glaciation, hence its high proportion of dissected lands (29.5 percent.) The southern Caribou-Targhee National Forest is dominated by relatively weak sedimentary rocks with only scattered glaciation.

Table 7. Highly-Dissected Lands in The GYA

| Administrative Unit | Highly-Dissected Acres | Total Unit Area (Acres)* | Percentage of Total Area |
|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 14,291 | 750,581 | 1.9% |
| Bridger-Teton N.F. | 147,277 | 3,462,802 | 4.3% |
| Caribou-Targhee N.F. *** | 343,580 | 2,094,976 | 16.4% |
| Custer N.F. | 32,544 | 525,302 | 6.2% |
| Gallatin N.F. | 168,062 | 2,124,751 | 7.9% |
| Grand Teton N.P.** | 1,801 | 333,139 | 0.5% |
| National Elk Refuge @ | - | 25,343 | 0.0% |
| Red Rock Wildlife Refuge | - | 58,811 | 0.0% |
| Shoshone N.F. | 727,097 | 2,466,963 | 29.5% |
| Yellowstone N.P. | 85,729 | 2,197,031 | 3.9% |
| Totals | 1,538,017 | 14,039,699 | 10.8% |

** Unit areas are for the Greater Yellowstone Area only. Above figures do not include 17,489 highly-dissected acres in private lands within Unit boundaries.

** Includes John D. Rockefeller Parkway

*** Modified from query output: 17,636 acres removed outside of GYA administrative boundary.

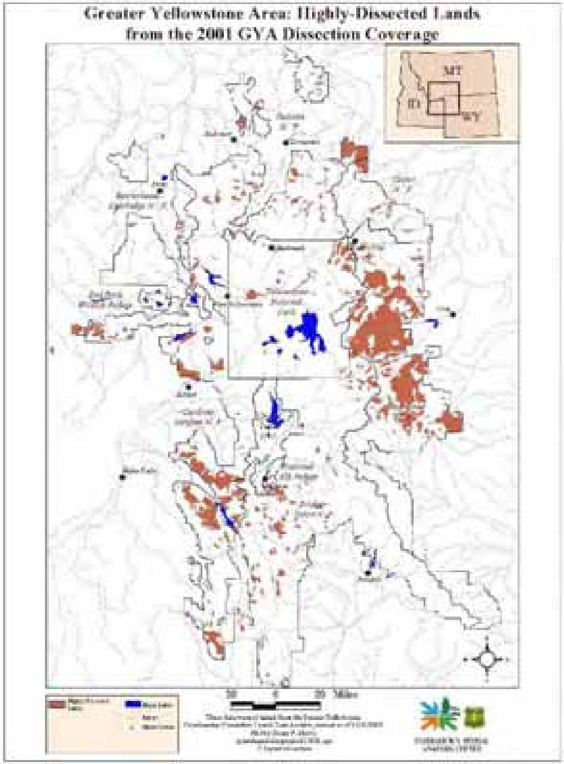



Figure 8. Greater Yellowstone Area: Highly-Dissected Lands from the 2001 GYA Dissection Coverage

### Landslides and Highly-Erodible Soils in the GYA

We used the modified landscape model described above to delineate highly-erodible soils and landslides for the GYA. Each was independently calculated, so there may be overlap where highly-erodible soils occur on landslide terrain. Each was tallied by administrative unit (Table 8 and D.) Distribution is shown in Figure 9.

Table 8. Highly-Erodible Soils in The GYA

| Administrative Unit | Erodible Soils (Acres) | Total Unit Area (Acres)* | Percentage of Total Area |
|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 96,713 | 589,259 | 16.4% |
| Bridger-Teton N.F. | 523,422 | 3,445,636 | 15.2% |
| Caribou-Targhee N.F. | 448,401 | 2,093,454 | 21.4% |
| Custer N.F. | 241,585 | 525,302 | 46.0% |
| Gallatin N.F. | 364,162 | 2,124,751 | 17.1% |
| Grand Teton N.P.** | 80,727 | 333,139 | 24.2% |
| National Elk Refuge @ | 11,795 | 25,343 | 46.5% |
| Red Rock Wildlife Refuge *** | na | na | na |
| Shoshone N.F. | 542,742 | 2,121,295 | 25.6% |
| Yellowstone N.P. | 480,791 | 2,197,031 | 21.9% |
| Totals | 2,790,337 | 13,455,209 | 20.7% |

* Unit areas are for the Greater Yellowstone Area only. Since erodible soil is rated only where landscape data is present, adjusted areas are used for administrative units. These are from Table 2.

** Includes John D. Rockefeller Parkway

*** no soils data

@ Highly-erodible lands in the National Elk Refuge from manually-removed acres in Grand Teton N. P.

Overall, 21 percent of the GYA has highly-erodible soil. This is consistent with the kinds of soils commonly occurring in the region (shallow, silty, or dominated by volcanic ash.) However, soil erodibility is only one component of landscape erosional potential. Therefore some of these ratings may not necessarily correlate with data on actual or potential erosion in a given area. The highest proportion (46.5 percent) of erodible soils occurred in the National Elk Refuge. This is because high silt content in the soil which increases erodibility. However, this is not necessarily correlated to erosion hazard, as the entire Refuge is on slopes less than two percent, resulting in low potential for erosion under current land use. The next highest proportion (46 percent) occurred in the Custer National Forest, primarily due to soil depth.

About eight percent of the GYA contains landslides or areas of potential slides. The Beaverhead-Deerlodge National Forest and the Caribou-Targhee National Forest have the highest proportions of landslide terrain (18 and 14 percent; Table 9.) Its distribution appears to be related to uplifted sedimentary rocks, especially in the Caribou-Targhee National Forest (Figure 9.)

Table 9. Landslides in The GYA

| Administrative Unit | Landslides (Acres) | Adjusted Total Unit Area (Acres)* | Percentage of Total Area |
|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 107,580 | 589,259 | 18.3% |
| Bridger-Teton N.F. | 272,745 | 3,445,636 | 7.9% |
| Caribou-Targhee N.F. | 295,574 | 2,093,454 | 14.1% |
| Custer N.F. | 534 | 525,302 | 0.1% |
| Gallatin N.F. | 139,602 | 2,124,751 | 6.6% |
| Grand Teton N.P.** | 8,011 | 333,139 | 2.4% |
| National Elk Refuge | - | 25,343 | 0.0% |
| Red Rock Wildlife Refuge *** | na | na | na |
| Shoshone N.F. | 214,913 | 2,121,295 | 10.1% |
| Yellowstone N.P. | 35,374 | 2,197,031 | 1.6% |
| Totals | 1,074,333 | 13,455,209 | 8.0% |

* Unit areas are for the Greater Yellowstone Area only. Since landslides are rated only where landscape data is present, adjusted areas are used for administrative units. These are from Table 2.

** Includes John D. Rockefeller Parkway

*** no soils data

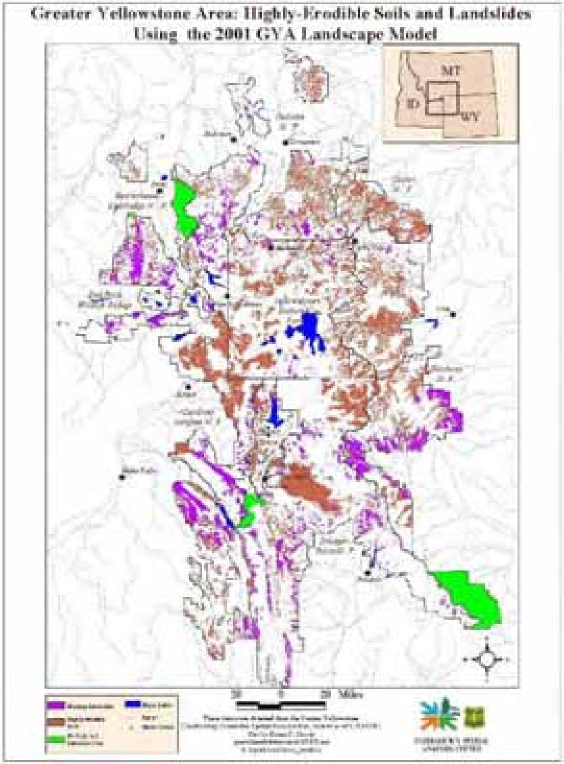



Figure 9. Greater Yellowstone Area: Highly-Erodible Soils and Landslides using the 2001 GYA Landscape Model

## Sensitive Lands

Sensitive lands (i.e. vulnerable lands) are either highly-dissected, highly-erodible, or have a significant landslide component. They are a significant proportion of the GYA (36 percent; Table 10.) Totals in Table 10 do not correspond well to totals from Table 8, Table 9, and Table 7. This is because overlap may occur between highly-erodible soils, dissected lands, or landslides. This is evident from a comparison of Figure 8 and Figure 9. On a unit basis, about 1/2 of the Shoshone National Forest, the Caribou-Targhee National Forest and the National Elk Refuge are vulnerable, but all units have significant proportions of sensitive lands.

The Unit Areas used here are slightly less than in Table 1, to account for missing landscape data. Since dissected lands may overlap these "no data" areas, some of these lands may also be counted as "sensitive". This may introduce some error, but comparing Figure 8 and Figure 9 shows this situation is uncommon.

Table 10. Highly-Sensitive Lands in The GYA

| Administrative Unit | Highly-Sensitive Lands (Acres) | Adjusted Unit Area (Acres) | Percentage of Effective Unit Area |
|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 209,432 | 589,259 | 35.5% |
| Bridger-Teton N.F. | 898,249 | 3,445,636 | 26.1% |
| Caribou-Targhee N.F. | 985,082 | 2,093,454 | 47.1% |
| Custer N.F. | 252,608 | 525,302 | 48.1% |
| Gallatin N.F. | 628,202 | 2,124,751 | 29.6% |
| Grand Teton N.P.** | 88,982 | 333,139 | 26.7% |
| National Elk Refuge | 11,795 | 25,343 | 46.5% |
| Red Rock Wildlife Refuge *** | na | na | na |
| Shoshone N.F. | 1,155,514 | 2,121,295 | 54.5% |
| Yellowstone N.P. | 559,706 | 2,197,031 | 25.5% |
| Totals | 4,789,570 | 13,455,209 | 35.6% |

* Unit areas are for the Greater Yellowstone Area only. Above figures do not include 17,488 highly-sensitive acres on private lands within Unit boundaries. Adjusted Unit Area equals total area less area having no soil and landscape data from Table 2. These are only approximately correct because dissected lands may cover these "no data" areas, thus being counted as "sensitive lands" regardless of soil and landscape data status.

** Includes John D. Rockefeller Parkway

*** no soils data

@ Sensitive (Highly-erodible) lands in the National Elk Refuge from manually-removed acres in Grand Teton N. P.

## Watershed Vulnerability using IWWI Watersheds and 2001 Landscape Model Data

### Queries

We intersected the 2001 Landscape Model coverage with the IWWI Watershed coverage. Other than clipping part of the Caribou-Targhee outside of the GYA, the watershed coverage is the same one used in the older IWWI vulnerability analysis. This was to meet the objective of consistently applying landscape criteria to the entire GYA while maintaining compatibility and comparability with the older IWWI vulnerability analysis. Note that since this is an intersection process the results can only be used to produce an approximate listing of all IWWI watersheds, since a few watersheds fall outside of the landscape model's boundaries and are therefore lost to analysis.

We imported the resulting attribute table to ACCESS ™ to facilitate analysis. Table 11 shows the query list used in the analysis. It is similar to the one in Table 6 other than calculations are on a HUC6 watershed basis, not solely on a unit basis. This structured sequence of queries facilitates future revisions of the model, since data changes do not affect the query definitions.

Table 11. Query List for Calculations of Missing Data Ratings and Vulnerability Ratings by 1999 IWWI HUC6 Watershed

| Query | Record Source (Table or Query) | Query Number* | Records |
|---|---|---|---|
| Create attribute table from relations | table | 26 | 73,967 |
| Select Valid Records from Attribute table | table | 29 | 72,610 |
| Initialize Sensitive Area Fields | table | 18 | 73,967 |
| Assigns Area based on Erodibility | 29 | 21 | 13,005 |
| Assigns Area based on Landslides and Dissection | 29 | 22 | 14,709 |
| Assigns No Data for Erodibility and Landslides | 29 | 19 | 9,568 |
| Re-assign sensitivity if dissected lands and no landscape data | 29 | 20 | 10,282 |
| Sum 'No Data' by HUC6 | 29 | 1 | 1,120 |
| Create Table of 'No Data' Ratings | 1 | 24 | 1,120 |
| Sum Vulnerability by HUC6 | 29 | 8 | 1,120 |
| Create Table of Vulnerability Ratings | 8 | 25 | 1,120 |
| Sum vulnerability ratings by unit for IWWI watersheds (Table 12) | 53 | 52 | 30 |

* Query descriptions and SQL are in Appendix Two.

### Ratings for Data Completeness

The process for rating vulnerability was to first sum all vulnerable lands in a given HUC6 watershed, then calculate a proportion of the entire area in that watershed. A rating is given based on the relative proportions (high = > 50%; moderate = 20 – 50%; low = < 20%.) Since there are some watersheds that have significant "no data" components, we also rated them for proportion of missing landscape data. This rating is similar to that used in the vulnerability ratings. We decided that any watershed having a "high" missing data rating would be excluded from further analysis. Note that we included lakes and large streams as well as missing landscape data for the "no data" classification. Only one watershed rated a "high" classification due to lakes. This was watershed 10070001002009 whose boundary is Yellowstone Lake in Yellowstone National Park. This rating was ignored in subsequent calculations that removed highly-rated missing-data watersheds.

Excluding Yellowstone Lake, fifty-two watersheds were rated "high" in missing data (Appendix Four.) These are concentrated in the southeastern portion of the Shoshone National Forest where watersheds fell outside the boundary of the landscape model (Figure 10.) The remainder were on the Beaverhead-Deerlodge National Forest and south of Jackson, Wyoming where attribute data were missing from the landscape model. Appendix Three contains examples of missing data ratings by watershed. Full listings are published separately.

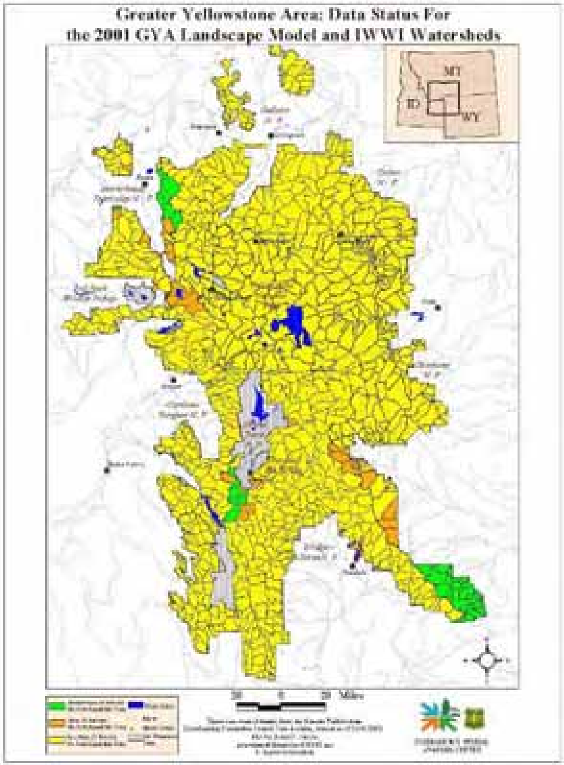



Figure 10. Greater Yellowstone Area: Data Status for the 2001 GYA Landscape Model and IWWI Watersheds.

**Ratings for Watershed Vulnerability**

The rating system for watershed vulnerability was similar to the methods used in determining data completeness. Note that vulnerability is rated on a unit and watershed basis, not a unit and polygon basis as in the sensitivity ratings given earlier in Table 10. Appendix Three contains examples of vulnerability ratings by watershed. Full listings are published separately.

Distribution of vulnerability over the GYA is shown in Figure 11. Table 12 shows watershed vulnerability ratings summed by administrative unit, based on the query in Table 11.

Table 12. GYA Watershed Vulnerability by IWWI HUC6 Watershed

| Administrative Unit | Watershed Acres on Unit by Rating @ | Vulnerability Rating | IWWI Watershed Area (Acres)* | IWWI HUC6 Watershed Area with High 'No Data' Status (Acres) *** | Effective Unit Area (Acres) | Percentage of Effective Unit Area |
|---|---|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 141,073 | High | 749,581 | 107,933 | 641,648 | 22.0% |
| | 173,508 | Low | | | | 27.0% |
| | 320,913 | Moderate | | | | 50.0% |
| Bridger-Teton N.F. | 563,979 | High | 3,459,073 | 72,046 | 3,387,027 | 16.7% |
| | 1,652,864 | Low | | | | 48.8% |
| | 1,170,958 | Moderate | | | | 34.6% |
| Caribou-Targhee N.F. | 919,853 | High | 2094976 | | 2,094,976 | 43.9% |
| | 451,017 | Low | | | | 21.5% |
| | 677,135 | Moderate | | | | 32.3% |
| Custer N.F. | 219,920 | High | 524,633 | | 524,633 | 41.9% |
| | 8,458 | Low | | | | 1.6% |
| | 296,358 | Moderate | | | | 56.5% |
| Gallatin N.F. | 298,980 | High | 2,116,407 | | 2,116,407 | 14.1% |
| | 715,892 | Low | | | | 33.8% |
| | 1,100,556 | Moderate | | | | 52.0% |
| Grand Teton N.P. | - | High | | | - | na |
| | - | Low | | | | na |
| | - | Moderate | | | | na |
| National Elk Refuge | - | High | | | - | na |
| | - | Low | | | | na |
| | - | Moderate | | | | na |
| Red Rock Wildlife Refuge | - | | | | - | na |
| Shoshone N.F. | 1,216,234 | High | 2,465,963 | 247,376 | 2,218,587 | 54.8% |
| | 269,369 | Low | | | | 12.1% |
| | 736,913 | Moderate | | | | 33.2% |
| Yellowstone N.P. ** | 196,204 | High | 2,181,108 | - | 2,181,108 | 9.0% |
| | 831,514 | Low | | | | 38.1% |
| | 1,153,392 | Moderate | | | | 52.9% |
| Greater Yellowstone Area | 3,556,243 | High | | | | 27.0% |
| | 4,102,621 | Low | | | | 31.2% |
| | 5,456,225 | Moderate | | | | 41.4% |

| | | | | |
|---|---|---|---|---|
| Totals | 13,115,089 | 13,591,742 | 427,355 | 13,164,387 |
| Private lands within Unit boundaries outside IWWI watersheds | 233,685 | | | |
| Unmapped Acres | 77,676 | | | |

* Data from Table 5.

** Yellowstone Lake (84,446 acres) is delineated as a watershed (10070001002009), and contains no landscape data. However, this watershed would be rated as "low" vulnerability, so was manually included under the "low" rating sum.

*** Data from Appendix Four.

@ Includes only HUC6 Watersheds with "Low" or "Moderate" Nodata Status

The Shoshone National Forest came out highest (55%) in highly sensitive watersheds (Table 12). Yellowstone National Park came out lowest with nine percent. Highly sensitive watersheds make up 27 percent of the area of the overall GYA. Red Rock Wildlife Refuge, Grand Teton National Park, and the National Wildlife Refuge were not rated, since we had no watershed data in those units. However, we do have landscape data in the latter two.

Turning to the distribution of vulnerability in Figure 11, highly vulnerable watersheds are concentrated in the northern two-thirds of the Shoshone National Forest, primarily due to highly dissected lands (Figure 8.) Dissection also plays a major role in the “high” ratings for watersheds in the mid-section of the Caribou-Targhee National Forest.

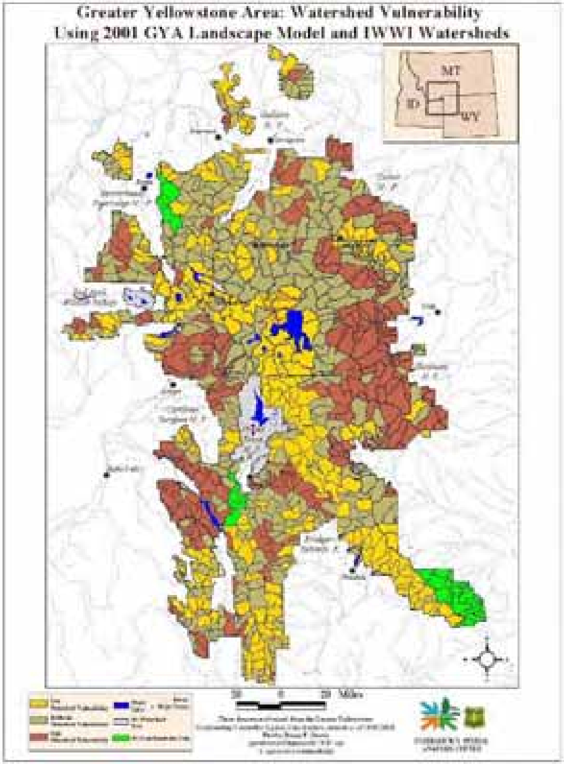



Figure 11. Greater Yellowstone Area: Watershed Vulnerability Using 2001 GYA Landscape Model and IWWI Watersheds

# Watershed Vulnerability using GYA Watersheds and 2001 Landscape Model Data

## Queries

We intersected the 2001 Landscape Model coverage with the GYA watershed coverage to meet the project objective of applying landscape criteria to the best watershed coverage available. This effectively updates both the vulnerability model and the watershed representation of the GYA. Note that since this is an intersection process the results can only be used to produce an approximate listing of all GYA watersheds, since a few watersheds fall outside of the landscape model's boundaries and are therefore lost to analysis.

As in the IWWI watershed-based analysis above, we imported the resulting attribute table to ACCESS ™ to facilitate analysis. Table 11 shows the query list used in the analysis. It is similar to the one in Table 6 other than calculations are on a HUC6 watershed basis, not solely on a unit basis. This structured sequence of queries facilitates future revisions of the model, since data changes do not affect the query definitions.

Table 13. Query List for Calculations of Missing Data Ratings and Vulnerability Ratings by 2000 GYA HUC6 Watershed

| Query | Record Source (Table or Query) | Query Number* | Records |
|---|---|---|---|
| Create attribute table from relations | table | 38 | 70,926 |
| Select Valid Records from Attribute table | table | 41 | 55,974 |
| Initialize Sensitive Area Fields | table | 55 | 70,926 |
| Assigns Area based on Erodibility | 41 | 21 | 9,696 |
| Assigns Area based on Landslides and Dissection | 41 | 22 | 11,222 |
| Assigns No Data for Erodibility and Landslides | 41 | 19 | 8,908 |
| Re-assign sensitivity if dissected lands and no landscape data | 41 | 20 | 7,963 |
| Sum 'No Data' by HUC6 | 41 | 1 | 753 |
| Create Table of 'No Data' Ratings | 1 | 24 | 753 |
| Sum Vulnerability by HUC6 | 41 | 8 | 753 |
| Create Table of Vulnerability Ratings | 8 | 25 | 753 |
| Sum vulnerability ratings by unit for IWWI watersheds (Table 14) | 50 | 56 | 29 |

* Query descriptions and SQL are in Appendix Two.

## Ratings for Data Completeness

The process for rating vulnerability was to first sum all vulnerable lands in a given HUC6 watershed, then calculate a proportion of the entire area in that watershed. A rating is given based on the relative proportions (high = > 50%; moderate = 20 – 50%; low = < 20%.) Since there are some watersheds that have significant "no data" components, we also rated them for proportion of missing landscape data. This rating is similar to that used in the vulnerability ratings. We decided that any watershed having a "high" missing data rating would be excluded from further analysis. Note that we included lakes and large streams as well as missing landscape data for the "no data" classification.

Forty-two watersheds were rated "high" in missing data (Appendix Five.) Large lakes and streams did not play a significant role in these watershed ratings (Figure 12.) The 42 watersheds are concentrated in the southeastern portion of the Shoshone National Forest where watersheds fell outside the boundary of the landscape model (Figure 12.) The remaining watersheds were on the Beaverhead-Deerlodge National Forest and south of Jackson, Wyoming where attribute data were missing from the landscape model. Appendix Three contains examples of missing data ratings by watershed. Full listings are published separately.

Both watershed coverages give similar, but not identical results in terms of missing data. This disparity occurs because watershed boundaries have been modified in the new GYA coverage, resulting in somewhat different included landscape data (Figure 10 and Figure 12.)

**Ratings for Watershed Vulnerability**

The rating system for watershed vulnerability was similar to the methods used in determining data completeness. Note that vulnerability is rated on a unit and watershed basis, not a unit and polygon basis as in the sensitivity ratings given earlier in Table 10. Appendix Three contains examples of vulnerability ratings by watershed. Full listings are published separately.

Distribution of vulnerability over the GYA is shown in Figure 13. Administrative boundaries are shown in the following map (Figure 14) to emphasize the seamless nature of the new watershed boundaries in Figure 13. Table 14 shows watershed vulnerability ratings summed by administrative unit, based on the query in Table 13. These administrative unit strata are approximate because unlike in the IWWI coverage, the GYA watershed boundaries do not always follow administrative boundaries.

Table 14. GYA Watershed Vulnerability by GYA HUC6 Watersheds Stratified by Administrative Units

| Administrative Unit | Watershed Acres on Unit by Rating @ | Vulnerability Rating | GYA Watershed Area (Acres)* | GYA HUC6 Watershed Area with High 'No Data' Status (Acres) *** | Effective Unit Area (Acres) | Percentage of Effective Unit Area |
|---|---|---|---|---|---|---|
| Beaverhead-Deerlodge N.F. | 151,154 | High | 750,466 | 117,066 | 633,400 | 23.9% |
| | 189,018 | Low | | | | 29.8% |
| | 293,149 | Moderate | | | | 46.3% |
| Bridger-Teton N.F. | 475,559 | High | 3,325,482 | 53,099 | 3,272,383 | 14.5% |
| | 1,528,394 | Low | | | | 46.7% |
| | 1,269,009 | Moderate | | | | 38.8% |
| Caribou-Targhee N.F. | 584,449 | High | 1,124,442 | | 1,124,442 | 52.0% |
| | 200,007 | Low | | | | 17.8% |
| | 344,621 | Moderate | | | | 30.6% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Custer N.F. | 218,429 | High | 525,302 | | 525,302 | 41.6% |
| | 7,826 | Low | | | | 1.5% |
| | 298,679 | Moderate | | | | 56.9% |
| Gallatin N.F. | 297,100 | High | 2,124,485 | | 2,124,485 | 14.0% |
| | 641,683 | Low | | | | 30.2% |
| | 1,157,463 | Moderate | | | | 54.5% |
| Grand Teton N.P. | 64,281 | High | 333,122 | | 333,122 | 19.3% |
| | 173,802 | Low | | | | 52.2% |
| | 95,228 | Moderate | | | | 28.6% |
| National Elk Refuge | 2,011 | High | 25,343 | | 25,343 | 7.9% |
| | - | Low | | | | 0.0% |
| | 23,332 | Moderate | | | | 92.1% |
| Red Rock Wildlife Refuge | - | | - | | | na |
| Shoshone N.F. | 1,246,805 | High | 2,466,951 | 247,319 | 2,219,632 | 56.2% |
| | 215,590 | Low | | | | 9.7% |
| | 757,159 | Moderate | | | | 34.1% |
| Yellowstone N.P. | 131,177 | High | 2,155,581 | | 2,155,581 | 6.1% |
| | 953,413 | Low | | | | 44.2% |
| | 1,070,990 | Moderate | | | | 49.7% |
| Greater Yellowstone Area | 3,170,965 | High | | | | 24.7% |
| | 3,909,734 | Low | | | | 30.5% |
| | 5,309,629 | Moderate | | | | 41.4% |
| Totals | 12,390,328 | | 12,831,174 | 417,484 | 12,413,690 | |
| Private lands within Unit boundaries within GYA watersheds | 243,237 | | | | | |

Note: These administrative unit strata are approximate as watershed boundaries do not always follow administrative boundaries for the GYA watershed coverage.

* Data from Table 4.

*** Data from Appendix Five.

@ Includes only HUC6 Watersheds with "Low" or "Moderate" Nodata Status

The Shoshone National Forest came out highest (56%) in highly vulnerable watersheds (Table 14). Yellowstone National Park came out lowest with six percent. Highly sensitive watersheds make up 25 percent of the area of the overall GYA. Red Rock Wildlife Refuge was not rated, since we had no watershed data nor landscape data in that unit. Calculations for the Caribou-Targhee National Forest are skewed because of the high proportion of missing watershed data (46 %; Table 4.)

Turning to the distribution of vulnerability in Figure 13, highly vulnerable watersheds are concentrated in the northern two-thirds of the Shoshone National Forest, primarily due to highly dissected lands (Figure 8.) Dissection also plays a major role in the “high” ratings in the mid-section of the Caribou-Targhee National Forest.

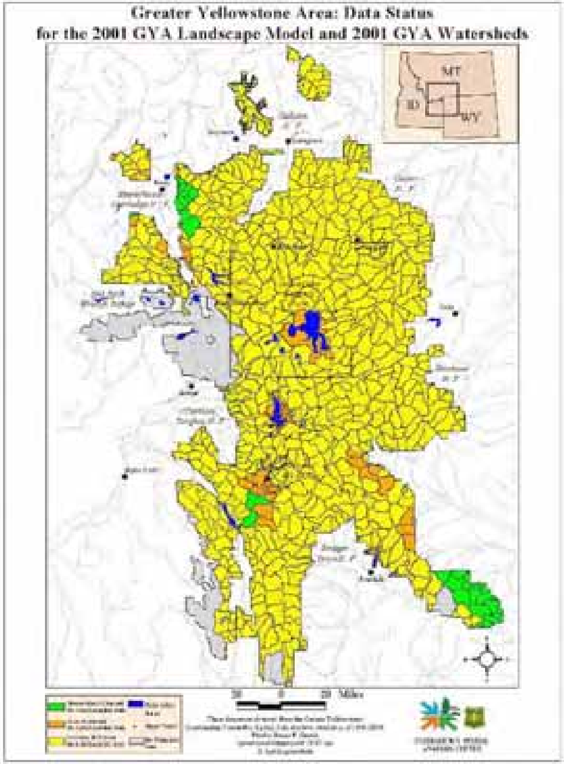



Figure 12. Greater Yellowstone Area: Data Status for the 2001 GYA Landscape Model and 2001 GYA Watersheds

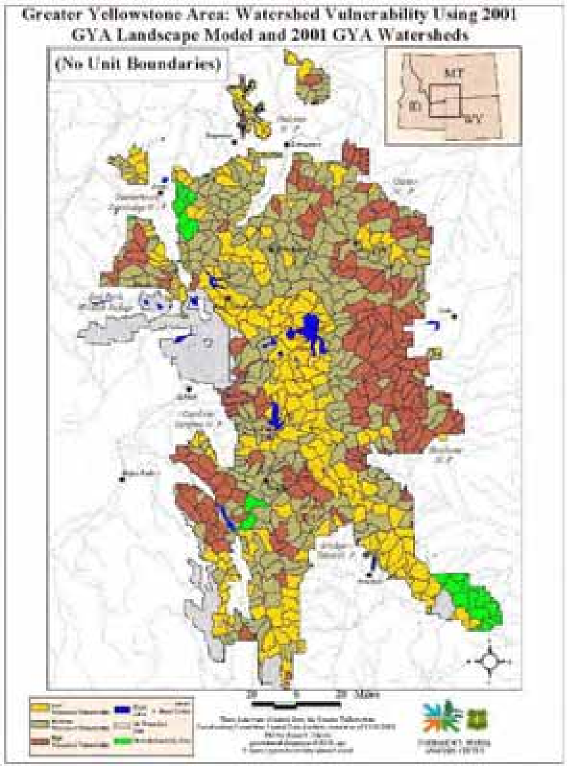



Figure 13. Greater Yellowstone Area: Watershed Vulnerability Using 2001 GYA Landscape Model and 2001 GYA Watersheds (No Unit Boundaries)

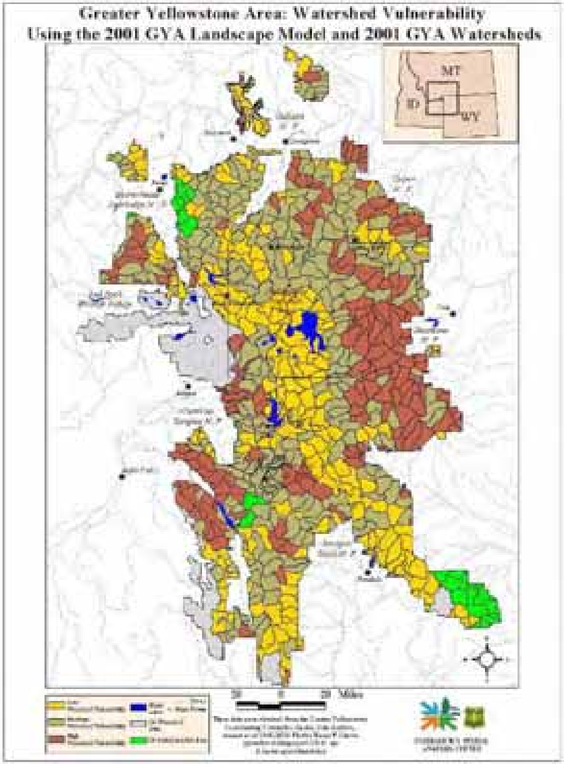



Figure 14. Greater Yellowstone Area: Watershed Vulnerability Using the 2001 GYA Landscape Model and 2001 GYA Watersheds

## Watershed Vulnerability using IWWI Watersheds and IWWI Vulnerability Data

Vulnerability ratings for this 1999 map were provided by the Forest Service (Figure 15.) The IWWI watersheds coverages were provided by unit, with an attribute designating the vulnerability rating for each watershed. The ratings were completed by individual units using a variety of methods based on professional judgment, and sent to a central location for compiling. We created the map, adding formatting only. Note that this project rated units we considered outside of GYA boundaries, notably on the western and southern parts of the Caribou-Targhee National Forest, the eastern part of the Custer National Forest, and the entire Beaverhead portion of the Beaverhead-Deerlodge National Forest.

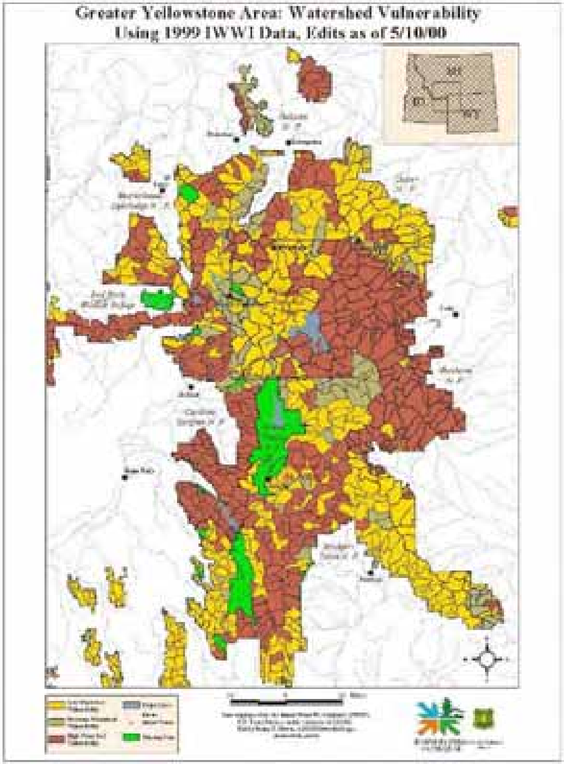



Figure 15. Greater Yellowstone Area: Watershed Vulnerability Using 1999 IWWI Data, Edits as of 5/10/00.

## Comparison of Results for Each Model

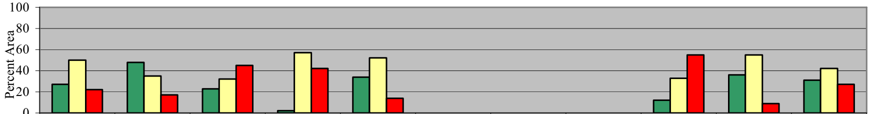
Figure 15 shows the original vulnerability ratings done in 1999, using 1999 IWWI watershed data and 1999 IWWI vulnerability ratings. Note extensive boundary differences, due to analysis differences as well as watershed definitions. Also note the extensive missing data in the core of the GYA.

Figure 11 shows the results of the model using the 1999 IWWI Watersheds and the 2001 GYA Landscape Model. As is often the case, the use of more detailed and accurate data has reduced the overall number of watersheds rated "high." Also, though the administrative boundaries are still evident, the ratings across them are much more consistent. There is a traceable process where we can identify exactly how any given polygon was rated for vulnerability. Also, these vulnerability ratings are consistent with the other ratings in the IWWI project, since they are based on the same watersheds. However, there is still missing data in the core of the GYA.

Figure 13 shows results of the model for the 2001 GYA watershed data and the 2001 GYA Landscape Model. As above, the use of more detailed and accurate data has reduced the overall number of watersheds rated "high." Though there are still some data gaps (notably in the watershed data for the Caribou-Targhee), the core of the GYA has been filled in. Administrative boundaries are now absent, partially due to the use of GYA-wide watershed data and partially due to the use of consistent rating methods across the GYA. This map represents an ideal situation, when coupled with additional pending data from Idaho. However, all other ratings (e.g. geomorphic integrity, stream channel conditions) would also need revising to make this compatible with the other aspects of the IWWI ratings.

We summarized ratings by unit for all three models in Figure 16, Figure 17, and Figure 18 Though individual units varied, the proportion of highly sensitive watersheds in the GYA was reduced by the new model (47% to 27% from Figures 17 and 16.) This is likely due to a combination of more detailed data, more included land area, and more consistent application of criteria used for defining sensitivity, but could also be from the conservative application of the rather general criteria given in the IWWI documentation. The large difference between ratings for the Custer National Forest may be due to the more detailed data being used in the landscape model. Earlier IWWI estimates were made without the benefit of the digital landscape coverage used here (Figure 9.)

Watershed Vulnerability by Administrative Unit for IWWI Watershed
Data and 2001 GYA Landscape Model Data*




| | Beaverhead Madison RD | Bridger-Teton | Caribou-Targhee | Custer Beartooth RD | Gallatin | Grand Teton | National Elk Refuge | Red Rock Wildlife Refuge | Shoshone | Yellowstone | GYA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Low | 27 | 48 | 23 | 2 | 34 | | | | 12 | 36 | 31 |
| 2 Moderate | 50 | 35 | 32 | 57 | 52 | | | | 33 | 55 | 42 |
| 3 High | 22 | 17 | 45 | 42 | 14 | | | | 55 | 9 | 27 |

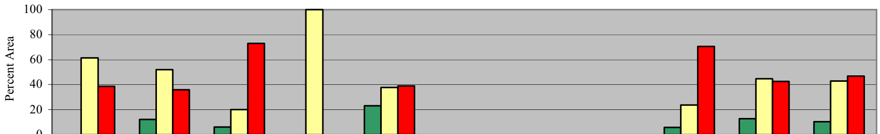
Administrative Unit

1 Low
2 Moderate
3 High

* From data in a report titled: " The Greater Yellowstone Area Watershed Vulnerability Model" by Henry Shovic, Gallatin National Forest, draft Dec. 2001.

Figure 16. Watershed Vulnerability by Unit for IWWI Watershed Data and 2001 GYA Landscape Model Data (from Table 12.)

Watershed Vulnerability by Administrative Unit for IWWI Watershed Data
and 1999 Reconnaisance Data (original) *



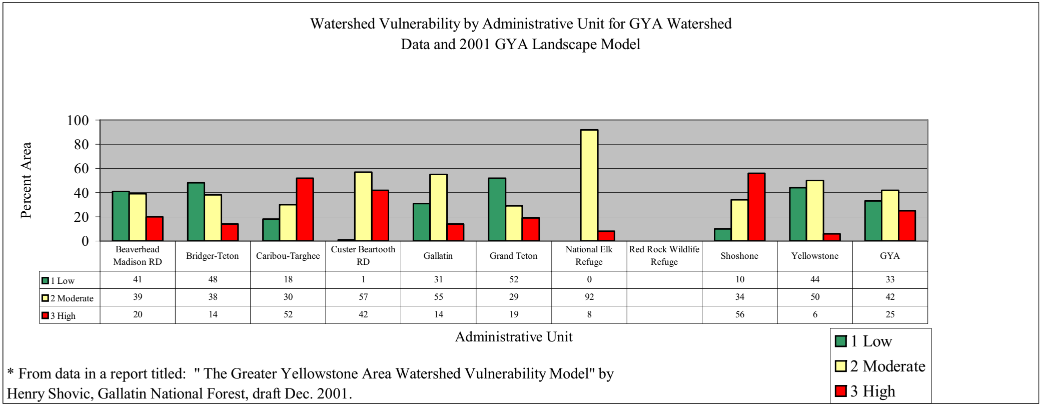

| | Beaverhead Madison RD | Bridger-Teton | Caribou-Targhee | Custer Beartooth RD | Gallatin | Grand Teton | National Elk Refuge | Red Rock Wildlife Refuge | Shoshone | Yellowstone | GYA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Low | 0 | 12 | 6 | 0 | 23 | | | | 6 | 13 | 10 |
| 2 Moderate | 61 | 52 | 20 | 100 | 38 | | | | 24 | 45 | 43 |
| 3 High | 39 | 36 | 73 | 0 | 39 | | | | 70 | 43 | 47 |

Administrative Unit

1 Low
2 Moderate
3 High

* From data in a report titled: "Watershed management strategy for the Greater Yellowstone Area, prepared for the Greater Yellowstone Committee, by the Greater Yellowstone Hydrologists, Spring 2000. By the Gallatin National Forest, box 130, Bozeman, MT. 58771

Figure 17. Watershed Vulnerability by Administrative Unit for IWWI Data and 1999 Reconnaissance Data (Original)




| | Beaverhead Madison RD | Bridger-Teton | Caribou-Targhee | Custer Beartooth RD | Gallatin | Grand Teton | National Elk Refuge | Red Rock Wildlife Refuge | Shoshone | Yellowstone | GYA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Low | 41 | 48 | 18 | 1 | 31 | 52 | 0 | | 10 | 44 | 33 |
| 2 Moderate | 39 | 38 | 30 | 57 | 55 | 29 | 92 | | 34 | 50 | 42 |
| 3 High | 20 | 14 | 52 | 42 | 14 | 19 | 8 | | 56 | 6 | 25 |

* From data in a report titled: " The Greater Yellowstone Area Watershed Vulnerability Model" by Henry Shovic, Gallatin National Forest, draft Dec. 2001.

Figure 18. Watershed Vulnerability by Administrative Unit for GYA Watershed Data and 2001 GYA Landscape Model (from Table 14.)

Here are a few specific comparisons between the original IWWI data and the new IWWI watershed-based data derived from Figure 17 and 16. In terms of watershed vulnerability, the Shoshone N. F. came out highest (55%) in highly sensitive watersheds versus 70 percent with the new model. This may be because of the systematic recognition of the highly dissected nature of most of the Forest (Figure 8.) Yellowstone National Park came out lowest with nine percent, versus a much more significant 43 percent. Though there is a recognized high erosion hazard in the eastern portion of the park (Figure 15) the criteria as established in the model did not emphasize that. Also, highly sensitive watersheds south of Yellowstone Lake were rated high partially due to the effects of the 1988 wildfires, not considered in the landscape model used here.

Some ratings on the Bridger-Teton National Forest were potentially inaccurate. Landscape data were very broadly defined in the northern portion of the Forest. This probably resulted in an under-assessment of vulnerability in this area. There also may be some missing landslide data in the map units representing the Flat Creek area south of the wilderness. Vulnerability ratings may be higher than shown here.

Finally, in terms of data completeness, landscape data was missing from about four percent of the entire GYA (Table 2.) Model results reflect this lack of data. It is unknown how much missing data are actually in the older IWWI results.

In terms of watersheds the IWWI watershed coverage actually was about five percent better than the newer GYA version of watersheds. In particular, watershed data was missing from the Caribou-Targhee because it was unavailable at publication time. However, Grand Teton N. P. and the National Wildlife Refuge were added, partially offsetting the C-T loss. No watershed or landscape data area available for the Red Rocks Wildlife Refuge, no doubt because of its relatively recent addition to the GYA.

# CONCLUSIONS

In this project we proposed to use published digital resource data, geographic information systems (GIS), and a modeling approach to build a model of watershed vulnerability for the entire GYA. Our goals were to eliminate or reduce 1) cross-administrative boundary differences in ratings; 2) data gaps; and 3) inconsistencies relating to differences in methods, quality, and scale of data available when the original ratings were made. We also wanted to produce a repeatable, testable, and documented model that can be re-used when data or criteria change, using corporate software and data formats. Finally, we wanted to utilize the most up-to-date information available, recognizing all spatial data is in a state of flux. We accomplished this by using standardized criteria reflecting the IWWI objectives, quantitative spatial data from the GYA, and objective programming and query-based models. We also designed the models to be procedure-based, not data-based, thereby making use of the most current data during our project. The final report is CDROM-based, and includes all watershed data, all procedures, all database data, and this report.

Our report includes extensive documentation of the processes we used, as well as the products. Why go to this kind of detail? The answer lies in the nature of resource management in the 21st century. One of the most consistent and frustrating parts of resource management today is that there are so many moving targets. Data changes daily. Scientific conclusions that yesterday had the weight of fact, today are questioned. We finish a project only to find that next month the judgment-based conclusions we sweated over to make our resource recommendations are now challenged by new data in digital form.

This trend is illustrated well in the Inland Water Ways Initiative. The older data were compiled for a large-scale reconnaissance project. Best available watershed data were used. Each specialist used professional judgment and available data to judge vulnerability by watershed. Some units chose not to participate or had no available specialists to complete the project. Three years later we review the results and it is obvious some no longer meet our management objectives. We have better data and better models. However, the project is finished, the personnel are largely gone, and documentation is limited.

Hence our approach: we consciously designed it from the ground up as a work in progress. Most of our effort in the 2001 vulnerability models has gone into developing relatively data-independent processes as well as products. We have a professional "distance" from the results, in that we maximized use of documented property-based analysis, and used a minimum of direct input from specialists.

Undoubtedly there will be concern as to how well the data matches previous publications and how well it matches professionals' concerns. We welcome these comments, as all models are a result of a specific set of assumptions, criteria, procedures, and data - any one of which may be in error. The point is none of these are hard-coded, nor are they hidden from view. As data, management objectives, professional criteria, or analytical tools change, the models can change with them, providing a longevity and at least a partial solution to the high and increasing pace of resource management analysis in the digital world.

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# APPENDICES

# Appendix One: VISUAL BASIC ™ Program for Defining "highly-erodible" map units based on soil and properties.

```
Option Compare Text
Option Explicit

'-------------------------------------------------------------
Sub GYA_erodibility()
'This sub reads soils information and adds to s58GYALandform field in the GYA standard table.
'
'H.Shovic
'092401  version 1.0

'initialize and dimension
Dim GYAStandard As DAO.Recordset
Dim dbs As Database
Set dbs = CurrentDb
Set GYAStandard = dbs.OpenRecordset("GYA model data with bvnf csnf cbnf", dbOpenDynaset)
Dim soilname, totalprop, compprop, erodsoil, counter, i, j, lithic, landslides, hydrothermal, otherskeletal, andisols, silty, nonsiltnonskmol, soiltest
GYAStandard.MoveFirst
counter = 0
lithic = 0
hydrothermal = 0
otherskeletal = 0
andisols = 0
silty = 0
nonsiltnonskmol = 0
'Soil Erodibility     check s10SoilComponentOne,s11SoilComponentTwo, s12SoilComponentThree, or s6SoilsSummary
'for the factors indicating "high" erodibility.
' if any are true, then place "highly erodible soil" in s58GYALandform field, otherwise place ""
' For any component the following selects for "high" erodibility
'If no rule fires, assume not highly erodible soils
'If no soils info, place "no soils data" in field.

checkerodibility:
soilname = ""
soiltest = ""
erodsoil = " "
landslides = " "
i = 1
GYAStandard.Edit
totalprop = 0
'assign the proper field and do the check for each field
'use soilsummary only if components are not present.
'If no component is present, check next component
Do While i <= 4
Select Case i
Case 1
   soilname = GYAStandard!s10SoilComponentOne
   If (IsNull(soilname)) Then soilname = ""
   soiltest = soilname
   If (soilname = "") Then GoTo nextsoilcomponent
   compprop = GYAStandard![s14SoilComponentOne%]
Case 2
   soilname = GYAStandard!s11SoilComponentTwo
   If (IsNull(soilname)) Then soilname = ""
   soiltest = soiltest + soilname
   If (soilname = "") Then GoTo nextsoilcomponent
   compprop = GYAStandard![s15SoilComponentTwo%]
Case 3
   soilname = GYAStandard!s12SoilComponentThree
   If (IsNull(soilname)) Then soilname = ""
   soiltest = soiltest + soilname
   If (soilname = "") Then GoTo nextsoilcomponent
   compprop = GYAStandard![s16SoilComponentThree%]
Case 4
   If (soiltest <> "") Then GoTo recordwrite  'if components present then write record
   soilname = GYAStandard!s6soilsSummary
```

```
    'if no components present, use summary
    If (IsNull(soilname)) Then soilname = "" 'if no soil data present, flag and do next record
    If (soilname = "") Then erodsoil = "no soils data": GoTo recordwrite

    End Select

'Selection criteria for soils in component fields, if summary used, go to another criteria list to account for
'multiple soils in one field.

 If i = 4 Then GoTo summary

    'for all these, either erodsoil is flagged or it is left as is to allow for previous component evaluation.

    'All lithic soils (skeletal or non-skeletal)are highly erodible
    If (soilname Like "*lithic*") Then
        lithic = lithic + 1
        erodsoil = "highly erodible soil"
        totalprop = totalprop + compprop
        GoTo nextsoilcomponent
    End If


    'all hydrothermal (skeletal or non-skeletal) soils are highly erodible, as evidenced by "thermic" temps, but only for YELL and with non-standard
terms
    If (soilname Like "*hydroth*" Or soilname Like "*Cryochrepts-HT*") Then
        hydrothermal = hydrothermal + 1
        erodsoil = "highly erodible soil"
        totalprop = totalprop + compprop
        GoTo nextsoilcomponent
    End If

    'nonskeletal soils high in silt are highly erodible.
    'This is placed above skeletal check statements, because use of these terms precludes skeletal designation in Taxonomy.  This
    'also accounts for soils that are "silty" over "sandy-skeletal" or other strongly contrasting particle size class groups.
    If (soilname Like "*fine-silty*") Then
        silty = silty + 1
        erodsoil = "highly erodible soil"
        totalprop = totalprop + compprop
        GoTo nextsoilcomponent
    End If

    If (soilname Like "*coarse-silty*") Then
        silty = silty + 1
        erodsoil = "highly erodible soil"
        totalprop = totalprop + compprop
        GoTo nextsoilcomponent
    End If
    'All other skeletal soils are not highly erodible
    If (soilname Like "*skeletal*") Then otherskeletal = otherskeletal + 1: GoTo nextsoilcomponent

    'non-skeletal Andisoils only, not Andic subgroups are highly erodible
    If (soilname Like "*cryands*") Then
        andisols = andisols + 1
        erodsoil = "highly erodible soil"
        totalprop = totalprop + compprop
        GoTo nextsoilcomponent
    End If

    'non-skeletal, non-silty Mollisols, non-Andisol, and soils in Mollic subgroups are not highly erodible.
    If (soilname Like "*mollic*") Then nonsiltnonskmol = nonsiltnonskmol + 1: GoTo nextsoilcomponent
    If (soilname Like "*cryoll*" Or soilname Like "*boroll*" Or soilname Like "*xeroll*" Or soilname Like "*aquoll*") Then nonsiltnonskmol =
nonsiltnonskmol + 1: GoTo nextsoilcomponent


    'MsgBox ("no rule fired, record number  = " & GYAStandard!S1MapUnitSymbol)

GoTo nextsoilcomponent
summary: ' for summary field only, go through criteria three times to approximate normal soil components.
' use 30% for each soil component, remove each already-used term to avoid double counting any criterion.
'The exception is where more than one criterion is met by a given soil in the summary.  This will double count those.
totalprop = 0
j = 0
```

```
summarybegin:
        'for all these, either erodsoil is flagged or it is left as is to allow for previous component evaluation.

        'All lithic soils (skeletal or non-skeletal)are highly erodible
        If (soilname Like "*lithic*") Then
            lithic = lithic + 1
            erodsoil = "highly erodible soil"
            totalprop = totalprop + 30
            soilname = ReplaceString_TSB((soilname), "lithic", "  ", False) 'remove string from soilname
        End If

        'all hydrothermal (skeletal or non-skeletal) soils are highly erodible, as evidenced by "thermic" temps, but only for YELL and with non-standard
terms
        If (soilname Like "*hydroth*" Or soilname Like "*Cryochrepts-HT*") Then
            hydrothermal = hydrothermal + 1
            erodsoil = "highly erodible soil"
            totalprop = totalprop + 30
            soilname = ReplaceString_TSB((soilname), "hydroth", "  ", False) 'remove string from soilname
            soilname = ReplaceString_TSB((soilname), "Cryochrepts-HT", "  ", False) 'remove string from soilname
        End If

        'nonskeletal soils high in silt are highly erodible.
        'This is placed above skeletal check statements, because use of these terms precludes skeletal designation in Taxonomy.  This
        'also accounts for soils that are "silty" over "sandy-skeletal" or other strongly contrasting particle size class groups.
        If (soilname Like "*fine-silty*") Then
            silty = silty + 1
            erodsoil = "highly erodible soil"
            totalprop = totalprop + 30
            soilname = ReplaceString_TSB((soilname), "fine-silty", "  ", False) 'remove string from soilname
        End If

        If (soilname Like "*coarse-silty*") Then
            silty = silty + 1
            erodsoil = "highly erodible soil"
            totalprop = totalprop + 30
            soilname = ReplaceString_TSB((soilname), "coarse-silty", "  ", False) 'remove string from soilname
        End If
        'All other skeletal soils are not highly erodible, except for Andisols
        If (soilname Like "*skeletal*") Then
            otherskeletal = otherskeletal + 1
            soilname = ReplaceString_TSB((soilname), "skeletal", "  ", False) 'remove string from soilname
        End If

        'non-skeletal Andisols only, not Andic subgroups are highly erodible
        If (soilname Like "*cryands*") Then
            andisols = andisols + 1
            erodsoil = "highly erodible soil"
            totalprop = totalprop + 30
            soilname = ReplaceString_TSB((soilname), "cryands", "  ", False) 'remove string from soilname
        End If

        'non-skeletal, non-silty Mollisols, non-Andisol, and soils in Mollic subgroups are not highly erodible.
        If (soilname Like "*mollic*") Then nonsiltnonskmol = nonsiltnonskmol + 1
        If (soilname Like "*cryoll*" Or soilname Like "*boroll*" Or soilname Like "*xeroll*" Or soilname Like "*aquoll*") Then nonsiltnonskmol =
nonsiltnonskmol + 1

        j = j + 1
  If j < 3 Then GoTo summarybegin

nextsoilcomponent:
i = i + 1

Loop

recordwrite:
If totalprop > 100 Then totalprop = 100
'check for previously assigned landslide designation, if there leave it
landslides = GYAStandard!s58GYALandform
If landslides = "landslides" Then GYAStandard!s58GYALandform = erodsoil + ", " + landslides: GoTo nextstep
GYAStandard!s58GYALandform = erodsoil
nextstep: GYAStandard![s67GeneralForest%] = totalprop
GYAStandard.Update
```

```
GYAStandard.MoveNext
counter = counter + 1
If GYAStandard.EOF Then GoTo finish

GoTo checkerodibility
finish:

MsgBox ("end, total records = " & counter)

MsgBox ("values of lithic, hydrothermal, otherskeletal, andisols, silty, nonsiltnonskmol" & lithic & " " & hydrothermal & " " & _
    "  " & otherskeletal & " " & andisols & " " & silty & " " & nonsiltnonskmol)



End Sub

Function ReplaceString_TSB(strTextIn As String, strFind As String, strReplace As String, fCaseSensitive As Integer) As String
  ' Comments   : replaces a substring in a string with another
  ' Parameters : strTextIn - string to work on
  '              strFind - string to find
  '              strReplace - string to replace with
  '              fCaseSensitive - True for case sensitive search, False for case-insensitive search
  ' Returns    : modified string
  '
  Dim strTmp As String
  Dim intPos As Integer
  Dim intCaseSensitive As Integer

  intCaseSensitive = IIf(fCaseSensitive, 2, 1)

  strTmp = strTextIn
  intPos = InStr(1, strTmp, strFind, intCaseSensitive)

  Do While intPos > 0
    strTmp = Left$(strTmp, intPos - 1) & strReplace & Mid$(strTmp, intPos + Len(strFind))
    intPos = InStr(intPos + Len(strReplace), strTmp, strFind, intCaseSensitive)
  Loop

  ReplaceString_TSB = strTmp


End Function
```

# Appendix Two: Database SQL Queries for the GYA Vulnerability Models

| Query Identifier | Structured Query Language (SQL) | Data Source * | Query Name |
|---|---|---|---|
| 1 | SELECT Sum([Selects valid records].ACRES_NO_DATA) AS [Acres with No Data], Sum([Selects valid records].acres) AS [Total Acres], [Selects valid records].HUC6<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].HUC6<br>ORDER BY [Selects valid records].HUC6; | IWWI, GYA | add no data acres by huc6 |
| 2 | SELECT Sum([Selects valid records].ACRES_NO_DATA) AS [Acres with No Data], Sum([Selects valid records].acres) AS [Total Acres], [Selects valid records].HUC6, [Selects valid records].s70SurveyArea<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].HUC6, [Selects valid records].s70SurveyArea<br>ORDER BY [Selects valid records].HUC6, [Selects valid records].s70SurveyArea; | IWWI, GYA | add no data acres by huc6 and unit |
| 3 | SELECT Sum([Selects valid records].ACRES_NO_DATA) AS [Acres with No Data], Sum([Selects valid records].acres) AS [Total Acres], [Selects valid records].s70SurveyArea<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].s70SurveyArea<br>ORDER BY [Selects valid records].s70SurveyArea; | IWWI, GYA | add no data acres by Unit |
| 4 | SELECT Sum([Selects valid records].ACRES_NO_DATA) AS [Acres with No Data], Sum([Selects valid records].acres) AS [Total Acres]<br>FROM [Selects valid records]; | IWWI, GYA | add no data acres for GYA |
| 5 | SELECT [Selects valid records].HUC6, Sum([Selects valid records].acres) AS [Total Acres]<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].HUC6; | IWWI, GYA | add total acres by HUC6 |
| 6 | SELECT Sum(([add total acres by HUC6].[Total ACRES])) AS [Total Area for HUC6], Avg(([add total acres by HUC6].[Total Acres])) AS [Average HUC6 Size], Min(([add total acres by HUC6].[Total Acres])) AS [Minimum HUC6 Size], Max(([add total acres by HUC6].[Total Acres])) AS [Maximum HUC6 Size]<br>FROM [add total acres by HUC6]; | IWWI, GYA | add total acres within HUC6 avg max min by HUC6 |
| 7 | SELECT Sum([Selects valid records].acres) AS SumOfacres<br>FROM [Selects valid records]; | IWWI, GYA | add total after removals |
| 8 | SELECT Sum([Selects valid records].ACRES_VULN) AS [Total Vulnerable Acres], Sum([Selects valid records].acres) AS [Total Acres], [Selects valid records].HUC6<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].HUC6; | IWWI, GYA | add vulnerable acres by huc6 |
| 9 | SELECT Sum([Selects valid records].ACRES_VULN) AS [Total Vulnerable Acres], Sum([Selects valid records].acres) AS [Total Acres], [Selects valid records].HUC6, [Selects valid records].UNIT<br>FROM [Selects valid records]<br>GROUP BY [Selects valid records].HUC6, [Selects valid records].UNIT<br>ORDER BY [Selects valid records].HUC6, [Selects valid records].UNIT; | IWWI | add vulnerable acres by huc6 and unit |
| 10 | SELECT Sum([Selects valid records erodible, landslides, dissection].ACRES_VULN) AS [Total Vulnerable Acres], Sum([Selects valid records erodible, landslides, dissection].acres) AS [Total Acres], [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>FROM [Selects valid records erodible, landslides, dissection]<br>GROUP BY [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>ORDER BY [Selects valid records erodible, landslides, dissection].s70SurveyArea; | IWWI | add vulnerable acres by Unit area |



Appendix Two: Database SQL Queries for the GYA Vulnerability Models

| | | | |
|---|---|---|---|
| 11 | SELECT Sum([Selects valid records erodible, landslides, dissection].ACRES_VULN) AS [Total Vulnerable Acres], Sum([Selects valid records erodible, landslides, dissection].acres) AS [Total Acres]<br>FROM [Selects valid records erodible, landslides, dissection]; | IWWI, GYA | add vulnerable acres for GYA from Unit area |
| 12 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES<br>FROM [Selects valid records erodible, landslides, dissection]<br>WHERE ((([Selects valid records erodible, landslides, dissection].DISSECTION)="high")); | UNIT | adds dissected area for GYA |
| 13 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES, [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>FROM [Selects valid records erodible, landslides, dissection]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides) Like "*highly erodible soil*"))<br>GROUP BY [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>ORDER BY [Selects valid records erodible, landslides, dissection].s70SurveyArea; | UNIT | adds erodible soil area by unit |
| 14 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES<br>FROM [Selects valid records erodible, landslides, dissection]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides) Like "*highly erodible soil*")); | UNIT | adds erodible soil area for GYA |
| 15 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES, [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>FROM [Selects valid records erodible, landslides, dissection]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides) Like "*landslides*"))<br>GROUP BY [Selects valid records erodible, landslides, dissection].s70SurveyArea<br>ORDER BY [Selects valid records erodible, landslides, dissection].s70SurveyArea; | UNIT | adds landslides area by unit |
| 16 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES<br>FROM [Selects valid records erodible, landslides, dissection]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides) Like "*landslides*")); | UNIT | adds landslides area for GYA |
| 18 | UPDATE iwwi_huc6_and_gyajoindiss_and_attributes SET iwwi_huc6_and_gyajoindiss_and_attributes.ACRES_VULN = 0, iwwi_huc6_and_gyajoindiss_and_attributes.ACRES_NO_DATA = 0; | IWWI | assigns 0 to ACRES_VULN and ACRES_NO_DATA |
| 19 | UPDATE [Selects valid records] SET [Selects valid records].ACRES_NO_DATA = [acres]<br>WHERE ((([Selects valid records].Erodible_landslides)="no soils data")); | IWWI, GYA | assigns acres_no_data for no soils data |
| 20 | UPDATE [Selects valid records] SET [Selects valid records].ACRES_NO_DATA = 0<br>WHERE ((([Selects valid records].DISSECTION)="high")); | IWWI, GYA | assigns acres_no_data back to 0 if high dissection |
| 21 | UPDATE [Selects valid records] SET [Selects valid records].ACRES_VULN = [Selects valid records].[acres]<br>WHERE ((([Selects valid records].Erodible_landslides)="highly erodible soil")); | IWWI, GYA | assigns erodible no reduction |
| 22 | UPDATE [Selects valid records] SET [Selects valid records].ACRES_VULN = [ACRES]<br>WHERE ((([Selects valid records].Erodible_landslides) Like "*landslides*")) OR ((([Selects valid records].DISSECTION)="high")); | IWWI, GYA | assigns landslides or dissected acres |
| 24 | SELECT [add no data acres by huc6].HUC6, [add no data acres by huc6].[Acres with No Data], [add no data acres by huc6].[Total Acres], [Acres with No Data]*100/[Total Acres] AS Percentage, IIf([Percentage]>50,"High",(IIf([Percentage]>20,"Moderate","Low"))) AS Rating INTO iwwiNo_Data_Percentages_HUC6<br>FROM [add no data acres by huc6]<br>ORDER BY [add no data acres by huc6].HUC6; | IWWI, GYA | Calculate percentage no data by HUC6 |
| 25 | SELECT [add vulnerable acres by huc6].HUC6, [add vulnerable acres by huc6].[Total Vulnerable Acres], [add vulnerable acres by huc6].[Total Acres], [Total Vulnerable Acres]*100/[Total Acres] AS Percentage, IIf([Percentage]>50,"High",(IIf([Percentage]>20,"Moderate","Low"))) AS Rating INTO iwwiVulnerable_Percentages_By_HUC6<br>FROM [add vulnerable acres by huc6]<br>ORDER BY [add vulnerable acres by huc6].HUC6; | IWWI, GYA | Calculate percentage vulnerable by HUC6 |

| | | | |
|---|---|---|---|
| 26 | SELECT iwwi_huc6_and_gya_join_diss.*, [area]*0.000247 AS acres, [GYA model data with bvnf csnf cbnf].*, 1.1 AS ACRES_VULN, 1.1 AS ACRES_NO_DATA INTO iwwi_huc6_and_gyajoindiss_and_attributes<br>FROM [GYA model data with bvnf csnf cbnf] RIGHT JOIN iwwi_huc6_and_gya_join_diss ON [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol = iwwi_huc6_and_gya_join_diss.LABEL; | IWWI | iwwi_huc6_and_gyajoindiss_and_attributesmak e |
| 27 | UPDATE [Selects records with attributes] SET [Selects records with attributes].ACRES = [ACRES]*([Perc_Of_Unit_Erodible]/100)<br>WHERE ((([Selects records with attributes].[Erodible_landslides]) Like "*highly erodible soil*")); | IWWI | reduces erodible acres by percentage of unit |
| 28 | SELECT gya_huc6_and_gyajoindiss_and_attributes.*, [gya_huc6_and_gyajoindiss_and_attributes].[s1MapUnitSymbol] AS Expr1, iwwi_huc6_and_gya_join_diss.*, [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol<br>FROM gya_huc6_and_gyajoindiss_and_attributes, [GYA model data with bvnf csnf cbnf] RIGHT JOIN iwwi_huc6_and_gya_join_diss ON [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol = iwwi_huc6_and_gya_join_diss.LABEL<br>WHERE ((([gya_huc6_and_gyajoindiss_and_attributes].[s1MapUnitSymbol]) Is Null) AND (([GYA model data with bvnf csnf cbnf].s1MapUnitSymbol) Is Null)); | IWWI | Selects records with no attributes |
| 29 | SELECT iwwi_huc6_and_gyajoindiss_and_attributes.*<br>FROM iwwi_huc6_and_gyajoindiss_and_attributes<br>WHERE (((iwwi_huc6_and_gyajoindiss_and_attributes.HUC6) Is Not Null) AND ((iwwi_huc6_and_gyajoindiss_and_attributes.LABEL)<>"" And (iwwi_huc6_and_gyajoindiss_and_attributes.LABEL)<>("CBNFP") And (iwwi_huc6_and_gyajoindiss_and_attributes.LABEL) Not Like "GLCO*")); | IWWI | Selects valid records |
| 30 | SELECT Sum([Selects records with no attributes].ACRES) AS SumOfACRES, [Selects records with no attributes].LABEL AS Expr1<br>FROM [Selects records with no attributes]<br>GROUP BY [Selects records with no attributes].LABEL; | IWWI | totals from Selects records with no attributes |
| 31 | SELECT Sum(([AREA]*0.000247)) AS [Total Acres], gyafs_bdy.MAP_NAME<br>FROM gyafs_bdy<br>GROUP BY gyafs_bdy.MAP_NAME; | GYA, IWWI | add admin acres from by unit |
| 32 | SELECT Sum([AREA]*0.000247) AS [Total Acres], gyafs_bdy_gyahuc6_clip.MAP_NAME<br>FROM gyafs_bdy_gyahuc6_clip<br>GROUP BY gyafs_bdy_gyahuc6_clip.MAP_NAME; | GYA | add admin acres from clipped by unit |
| 33 | SELECT Sum([Selects valid records erodible, landslides, dissection].acres) AS SumOfACRES, [Selects valid records erodible, landslides, dissection].s70SurveyArea, [Selects valid records erodible, landslides, dissection].DISSECTION<br>FROM [Selects valid records erodible, landslides, dissection]<br>GROUP BY [Selects valid records erodible, landslides, dissection].s70SurveyArea, [Selects valid records erodible, landslides, dissection].DISSECTION<br>HAVING ((([Selects valid records erodible, landslides, dissection].DISSECTION)="high"))<br>ORDER BY [Selects valid records erodible, landslides, dissection].s70SurveyArea; | UNIT | adds dissected land area by unit |
| 36 | SELECT [add admin acres from by unit].[Total Acres], [add admin acres from clipped by unit].*, [add admin acres from by unit].[Total Acres]-[add admin acres from clipped by unit].[total acres] AS [Acres Not in GYA_HUC6], [Acres Not in GYA_HUC6]*100/[add admin acres from by unit].[Total Acres] AS [Percentage Not in GYA_HUC6]<br>FROM [add admin acres from by unit] INNER JOIN [add admin acres from clipped by unit] ON [add admin acres from by unit].MAP_NAME = [add admin acres from clipped by unit].MAP_NAME; | GYA | calculates percentage admin not in gya_huc6 |

| | | | |
|---|---|---|---|
| 37 | SELECT gyajoindissshape.*, [area]*0.000247 AS acres, [GYA model data with bvnf csnf cbnf].* INTO gyajoindiss_and_attributes<br>FROM gyajoindissshape LEFT JOIN [GYA model data with bvnf csnf cbnf] ON gyajoindissshape.LABEL = [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol; | GYA | gyajoindiss_and_attributesmake |
| 38 | SELECT gya_huc6_and_gyajoindiss.*, [area]*0.000247 AS acres, [GYA model data with bvnf csnf cbnf].*, 1.1 AS ACRES_VULN, 1.1 AS ACRES_NO_DATA INTO gya_huc6_and_gyajoindiss_and_attributes<br>FROM [GYA model data with bvnf csnf cbnf] RIGHT JOIN gya_huc6_and_gyajoindiss ON [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol = gya_huc6_and_gyajoindiss.LABEL; | GYA | gya_huc6_and_gyajoindiss_and_attributesmake |
| 39 | SELECT gya_huc6_and_gyajoindiss_and_attributes.*, gya_huc6_and_gyajoindiss_and_attributes.s1MapUnitSymbol<br>FROM gya_huc6_and_gyajoindiss_and_attributes<br>WHERE (((gya_huc6_and_gyajoindiss_and_attributes.s1MapUnitSymbol) Is Null)); | GYA | Selects records with no attributes |
| 40 | SELECT Sum([Selects records with no attributes].acres) AS SumOfACRES, [Selects records with no attributes].LABEL<br>FROM [Selects records with no attributes]<br>GROUP BY [Selects records with no attributes].LABEL; | GYA | totals from Selects records with no attributes |
| 41 | SELECT gya_huc6_and_gyajoindiss_and_attributes.*<br>FROM gya_huc6_and_gyajoindiss_and_attributes<br>WHERE (((gya_huc6_and_gyajoindiss_and_attributes.LABEL) Is Not Null And (gya_huc6_and_gyajoindiss_and_attributes.LABEL) Not Like "GLCO*") AND ((gya_huc6_and_gyajoindiss_and_attributes.HUC6) Is Not Null)); | GYA | Selects valid records |
| 42 | SELECT gyajoindiss_and_attributes.*<br>FROM gyajoindiss_and_attributes<br>WHERE (((gyajoindiss_and_attributes.LABEL) Is Not Null And (gyajoindiss_and_attributes.LABEL) Not Like "GLCO*")); | UNIT | Selects valid records erodible, landslides, dissection |
| 43 | UPDATE gyajoindiss_and_attributes SET gyajoindiss_and_attributes.ACRES_VULN = 0, gyajoindiss_and_attributes.ACRES_NO_DATA = 0; | UNIT | Unit area: assigns 0 to ACRES_VULN and ACRES_NO_DATA |
| 44 | UPDATE [Selects valid records erodible, landslides, dissection] SET [Selects valid records erodible, landslides, dissection].ACRES_VULN = [Selects valid records].[acres]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides)="highly erodible soil")); | UNIT | Unit area: assigns erodible no reduction |
| 45 | UPDATE [Selects valid records erodible, landslides, dissection] SET [Selects valid records erodible, landslides, dissection].ACRES_VULN = [ACRES]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides) Like "*landslides*")) OR ((([Selects valid records erodible, landslides, dissection].DISSECTION)="high")); | UNIT | Unit Area: assigns landslides or dissected acres |
| 46 | UPDATE [Selects valid records erodible, landslides, dissection] SET [Selects valid records erodible, landslides, dissection].ACRES_NO_DATA = [acres]<br>WHERE ((([Selects valid records erodible, landslides, dissection].Erodible_landslides)="no soils data")); | UNIT | Unit area: assigns acres_no_data for no soils data |
| 47 | UPDATE [Selects valid records erodible, landslides, dissection] SET [Selects valid records erodible, landslides, dissection].ACRES_NO_DATA = 0<br>WHERE ((([Selects valid records erodible, landslides, dissection].DISSECTION)="high")); | UNIT | Unit area: assigns acres_no_data back to 0 if high dissection |
| 48 | SELECT Sum([add area by unit by rating by gya_huc6].[Total Acres]) AS [SumOfTotal Acres], [add area by unit by rating by gya_huc6].MAP_NAME<br>FROM [add area by unit by rating by gya_huc6]<br>GROUP BY [add area by unit by rating by gya_huc6].MAP_NAME; | GYA | adds huc6 area by unit |
| 49 | SELECT Sum(iwwi_huc6_and_gyajoindiss_and_attributes.acres) AS SumOfacres, iwwi_huc6_and_gyajoindiss_and_attributes.UNIT<br>FROM iwwi_huc6_and_gyajoindiss_and_attributes<br>GROUP BY iwwi_huc6_and_gyajoindiss_and_attributes.UNIT; | IWWI | add area by unit iwwi |

| | | | |
|---|---|---|---|
| 50 | SELECT Sum([AREA]*0.000247) AS [Total Acres], gyafs_bdy_and_gya_huc6_fed_lands_only.MAP_NAME, GYAVulnerable_Percentages_By_HUC6.Rating, GYAVulnerable_Percentages_By_HUC6.HUC6<br>FROM GYANo_Data_Percentages_HUC6 RIGHT JOIN (GYAVulnerable_Percentages_By_HUC6 LEFT JOIN gyafs_bdy_and_gya_huc6_fed_lands_only ON GYAVulnerable_Percentages_By_HUC6.HUC6 = gyafs_bdy_and_gya_huc6_fed_lands_only.HUC6) ON GYANo_Data_Percentages_HUC6.HUC6 = GYAVulnerable_Percentages_By_HUC6.HUC6<br>WHERE (((GYANo_Data_Percentages_HUC6.Rating)<>"High"))<br>GROUP BY gyafs_bdy_and_gya_huc6_fed_lands_only.MAP_NAME, GYAVulnerable_Percentages_By_HUC6.Rating, GYAVulnerable_Percentages_By_HUC6.HUC6<br>ORDER BY gyafs_bdy_and_gya_huc6_fed_lands_only.MAP_NAME, GYAVulnerable_Percentages_By_HUC6.Rating DESC , GYAVulnerable_Percentages_By_HUC6.HUC6; | GYA | add area by unit by rating by gya_huc6 |
| 52 | SELECT Sum([add area by unit by rating by iwwi_huc6].[Total Acres]) AS [Sum of Acres], [add area by unit by rating by iwwi_huc6].MAP_NAME, [add area by unit by rating by iwwi_huc6].Rating<br>FROM [add area by unit by rating by iwwi_huc6]<br>GROUP BY [add area by unit by rating by iwwi_huc6].MAP_NAME, [add area by unit by rating by iwwi_huc6].Rating; | IWWI | adds huc6 area by unit by rating_iwwi_huc6 |
| 53 | SELECT Sum([iwwi_huc6_and_gyafs_bdyunion].[AREA]*0.000247) AS [Total Acres], iwwi_huc6_and_gyafs_bdyunion.MAP_NAME, iwwiVulnerable_Percentages_By_HUC6.Rating, iwwi_huc6_and_gyafs_bdyunion.HUC6, iwwi_huc6_and_gyafs_bdyunion.MAP_NAME<br>FROM iwwiNo_Data_Percentages_HUC6 RIGHT JOIN (iwwi_huc6_and_gyafs_bdyunion RIGHT JOIN iwwiVulnerable_Percentages_By_HUC6 ON iwwi_huc6_and_gyafs_bdyunion.HUC6 = iwwiVulnerable_Percentages_By_HUC6.HUC6) ON iwwiNo_Data_Percentages_HUC6.HUC6 = iwwiVulnerable_Percentages_By_HUC6.HUC6<br>WHERE (((iwwiNo_Data_Percentages_HUC6.Rating)<>"High"))<br>GROUP BY iwwi_huc6_and_gyafs_bdyunion.MAP_NAME, iwwiVulnerable_Percentages_By_HUC6.Rating, iwwi_huc6_and_gyafs_bdyunion.HUC6<br>ORDER BY iwwi_huc6_and_gyafs_bdyunion.MAP_NAME, iwwiVulnerable_Percentages_By_HUC6.Rating DESC , iwwi_huc6_and_gyafs_bdyunion.HUC6; | IWWI | add area by unit by rating by iwwi_huc6 |

| | | | |
|---|---|---|---|
| 54 | SELECT [GYA model data with bvnf csnf cbnf].s1MapUnitSymbol, [GYA model data with bvnf csnf cbnf].s19LandformSummary, [GYA model data with bvnf csnf cbnf].s21LandformOne, [GYA model data with bvnf csnf cbnf].s22LandformTwo, [GYA model data with bvnf csnf cbnf].s23LandformThree, [GYA model data with bvnf csnf cbnf].s6SoilsSummary, [GYA model data with bvnf csnf cbnf].s5MapUnitNotes, [GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary, [GYA model data with bvnf csnf cbnf].Erodible_landslides<br>FROM [GYA model data with bvnf csnf cbnf]<br>WHERE ((([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s23LandformThree) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s22LandformTwo) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s21LandformOne) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s19LandformSummary) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s6SoilsSummary) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s5MapUnitNotes) Like "*unstable*")) OR ((([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*slide*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*mass*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*earth*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*flow*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*slump*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*glide*" Or ([GYA model data with bvnf csnf cbnf].s27ParentMaterialSummary) Like "*unstable*")); | GYA, IWWI | landslides filter for later manual selection |
| 55 | UPDATE gya_huc6_and_gyajoindiss_and_attributes SET gya_huc6_and_gyajoindiss_and_attributes.ACRES_VULN = 0, gya_huc6_and_gyajoindiss_and_attributes.ACRES_NO_DATA = 0; | GYA | assigns 0 to ACRES_VULN and ACRES_NO_DATA |
| 56 | SELECT Sum([add area by unit by rating by gya_huc6].[Total Acres]) AS [SumOfTotal Acres], [add area by unit by rating by gya_huc6].MAP_NAME, [add area by unit by rating by gya_huc6].Rating<br>FROM [add area by unit by rating by gya_huc6]<br>GROUP BY [add area by unit by rating by gya_huc6].MAP_NAME, [add area by unit by rating by gya_huc6].Rating; | GYA | adds huc6 area by unit by rating |

*

- UNIT = Based on 2001 Landscape data, not on Watershed data  (contained in "gyaHuc6_and_gyajoindiss summaries.mdb")
- GYA = Based on 2001 Landscape data and 2001 GYA Watershed database  (contained in "gyaHuc6_and_gyajoindiss summaries.mdb")
- IWWI= Based on 2001 Landscape data and 1999 IWWI Watershed data  (contained in "iwwiHuc6_and_gyajoindiss summaries.mdb")

Multiple designations mean queries are universal between databases.

## Appendix Three. Summaries of Vulnerability and Data Completeness by IWWI and GYA Watersheds: Examples of Reports contained on the publication CD.

These reports are examples of data available in electronic form. The first and last page of each report is included here. The first reports are for the IWWI coverage and GYA landscape Model. The second set is for the GYA watershed coverage and the GYA landscape Model. Totals in these reports do not correspond exactly to tables in the model analysis. This is because these reports also include watersheds having "high" no data levels and do not include sensitive lands in the GYA that are not in the GYA watershed coverage.

# GYA Watershed Vulnerability (IWWI HUC6)

## Ratings for Watersheds or portions thereof in Federal ownership only.

Henry F. Shovic, Interagency Spatial Analysis Center

| HUC6 Watershed | Sensitive Lands (Acres) | Total Acres | Percentage of | Watershed Vulnerability Rating |
|---|---|---|---|---|
| 10020001070 | 180.0 | 279.3 | 64.5 | High |
| 10020001070 | 75.7 | 258.7 | 29.3 | Moderate |
| 10020001080 | 63.7 | 183.8 | 34.7 | Moderate |
| 10020001080 | 0.0 | 67.0 | 0.0 | Low |
| 10020001100 | 29.7 | 519.4 | 5.7 | Low |
| 10020001100 | 0.0 | 30.3 | 0.0 | Low |
| 10020001100 | 0.0 | 153.5 | 0.0 | Low |
| 10020001180 | 0.0 | 4.2 | 0.0 | Low |
| 10020001190 | 0.0 | 76.9 | 0.0 | Low |
| 10020001190 | 0.4 | 1.0 | 39.9 | Moderate |
| 10020001190 | 0.0 | 3.5 | 0.0 | Low |
| 10020001190 | 0.0 | 29.2 | 0.0 | Low |
| 10020001190 | 683.3 | 2531.9 | 27.0 | Moderate |
| 10020001190 | 424.4 | 1243.3 | 34.1 | Moderate |
| 10020001190 | 3305.5 | 5038.4 | 65.6 | High |
| 10020001190 | 5624.7 | 17430.1 | 32.3 | Moderate |
| 10020001200 | 0.0 | 1.7 | 0.0 | Low |
| 10020001200 | 2397.0 | 2956.0 | 81.1 | High |
| 10020001210 | 800.7 | 5451.7 | 14.7 | Low |
| 10020001210 | 19.4 | 22.1 | 88.0 | High |
| 10020001210 | 749.9 | 1319.1 | 56.8 | High |
| 10020001220 | 0.0 | 1298.1 | 0.0 | Low |
| 10020001220 | 1757.8 | 4448.3 | 39.5 | Moderate |
| 10020002170 | 6777.3 | 13209.2 | 51.3 | High |
| 10020002180 | 980.9 | 1813.0 | 54.1 | High |
| 10020002180 | 1730.7 | 8482.3 | 20.4 | Moderate |
| 10020003010 | 66.8 | 802.1 | 8.3 | Low |
| 10020003010 | 3732.6 | 10054.3 | 37.1 | Moderate |
| 10020003010 | 1936.4 | 6782.2 | 28.6 | Moderate |
| 10020003020 | 2752.3 | 13203.6 | 20.8 | Moderate |
| 10020003030 | 40.0 | 134.4 | 29.8 | Moderate |
| 10020003040 | 2275.8 | 10305.2 | 22.1 | Moderate |
| 10020003040 | 1210.8 | 4574.0 | 26.5 | Moderate |
| 10020003050 | 2043.1 | 8816.9 | 23.2 | Moderate |
| 10020003050 | 2.9 | 260.8 | 1.1 | Low |
| 10020003070 | 248.3 | 2559.7 | 9.7 | Low |
| 10020003070 | 0.0 | 119.7 | 0.0 | Low |
| 10020003080 | 5632.8 | 16463.3 | 34.2 | Moderate |
| 10020003080 | 4122.3 | 11584.1 | 35.6 | Moderate |
| 10020003090 | 17235.5 | 32665.1 | 52.8 | High |
| 10020003100 | 17607.7 | 34508.7 | 51.0 | High |
| 10020003100 | 8248.0 | 12992.8 | 63.5 | High |
| 10020003110 | 7699.0 | 27370.7 | 28.1 | Moderate |
| 10020003110 | 8051.9 | 10427.4 | 77.2 | High |

| HUC6 Watershed | Sensitive Lands (Acres) | Total Acres | Percentage of | Watershed Vulnerability Rating |
|---|---|---|---|---|
| 17040214040 | 902.2 | 4586.2 | 19.7 | Low |
| 17040214040 | 7200.8 | 11528.6 | 62.5 | High |
| 17040214040 | 5121.8 | 9996.1 | 51.2 | High |
| 17040214040 | 3069.6 | 5985.0 | 51.3 | High |
| 17040214040 | 5859.9 | 8500.6 | 68.9 | High |
| 17040214040 | 8229.8 | 19918.8 | 41.3 | Moderate |
| 17040214040 | 2643.1 | 5896.3 | 44.8 | Moderate |
| 17040214040 | 127.2 | 7267.6 | 1.8 | Low |
| 17040214041 | 2153.2 | 5179.5 | 41.6 | Moderate |
| 17040214060 | 11.8 | 1578.1 | 0.7 | Low |
| 17040214060 | 6163.1 | 33145.6 | 18.6 | Low |
| 17040214060 | 0.0 | 1908.0 | 0.0 | Low |
| 17040214060 | 262.4 | 8969.2 | 2.9 | Low |
| 17040214060 | 4719.1 | 16811.5 | 28.1 | Moderate |
| 17040214060 | 1004.9 | 3782.9 | 26.6 | Moderate |
| 17040215020 | 6.8 | 3042.0 | 0.2 | Low |
| 17040215030 | 0.0 | 1562.0 | 0.0 | Low |
| 17040215030 | 2197.4 | 9564.4 | 23.0 | Moderate |
| 17040215030 | 0.0 | 13116.0 | 0.0 | Low |
| 17040215030 | 551.0 | 15649.6 | 3.5 | Low |
| 17040215040 | 1855.7 | 12484.3 | 14.9 | Low |
| 17040215040 | 1008.6 | 15381.6 | 6.6 | Low |
| 17040215050 | 200.0 | 3021.9 | 6.6 | Low |
| 17040215050 | 0.0 | 14240.9 | 0.0 | Low |
| 17040215050 | 795.7 | 9480.8 | 8.4 | Low |
| 17040215050 | 847.7 | 21280.3 | 4.0 | Low |
| 17040215050 | 1655.5 | 5772.8 | 28.7 | Moderate |
| 17040215060 | 921.5 | 944.9 | 97.5 | High |
| 17040215060 | 8340.5 | 8354.5 | 99.8 | High |
| 17040215060 | 5986.4 | 12534.4 | 47.8 | Moderate |
| 17040216020 | 0.0 | 5231.0 | 0.0 | Low |
| 17040216020 | 0.0 | 425.4 | 0.0 | Low |
| 17040216030 | 0.0 | 7284.9 | 0.0 | Low |
| 17040216030 | 0.0 | 9212.6 | 0.0 | Low |
| 17040216030 | 0.0 | 17344.5 | 0.0 | Low |
| 17040216040 | 0.0 | 13026.6 | 0.0 | Low |
| 17040216050 | 0.0 | 1348.7 | 0.0 | Low |
| 17040216060 | 438.5 | 10455.8 | 4.2 | Low |
| ***Statistics:*** | ***Total*** 4,695,914.3 | ***Total*** 13,505,540.8 | ***Average*** 34.9 | |

# GYA Landscape Data Completeness (IWWI HUC6)

***Ratings for HUC6 Watersheds or portions thereof in Federal ownership only. Henry F. Shovic, Interagency Spatial Analysis Center***

| HUC6 Watershed | Acres with Incomplete Landscape Data | Total Acres | Percentage of Total Acres | Rating for missing data: low < 20%; mod 20-50%; high >50% |
|---|---|---|---|---|
| 10020001070 | 0.0 | 279.3 | 0.0 | Low |
| 10020001070 | 0.0 | 258.7 | 0.0 | Low |
| 10020001080 | 0.0 | 183.8 | 0.0 | Low |
| 10020001080 | 0.0 | 67.0 | 0.0 | Low |
| 10020001100 | 0.0 | 519.4 | 0.0 | Low |
| 10020001100 | 0.0 | 30.3 | 0.0 | Low |
| 10020001100 | 0.0 | 153.5 | 0.0 | Low |
| 10020001180 | 0.0 | 4.2 | 0.0 | Low |
| 10020001190 | 0.0 | 76.9 | 0.0 | Low |
| 10020001190 | 0.0 | 1.0 | 0.0 | Low |
| 10020001190 | 0.0 | 3.5 | 0.0 | Low |
| 10020001190 | 0.0 | 29.2 | 0.0 | Low |
| 10020001190 | 75.2 | 2,531.9 | 3.0 | Low |
| 10020001190 | 57.4 | 1,243.3 | 4.6 | Low |
| 10020001190 | 223.3 | 5,038.4 | 4.4 | Low |
| 10020001190 | 136.9 | 17,430.1 | 0.8 | Low |
| 10020001200 | 0.0 | 1.7 | 0.0 | Low |
| 10020001200 | 32.6 | 2,956.0 | 1.1 | Low |
| 10020001210 | 1,439.5 | 5,451.7 | 26.4 | Moderate |
| 10020001210 | 0.0 | 22.1 | 0.0 | Low |
| 10020001210 | 0.0 | 1,319.1 | 0.0 | Low |
| 10020001220 | 173.3 | 1,298.1 | 13.4 | Low |
| 10020001220 | 322.7 | 4,448.3 | 7.3 | Low |
| 10020002170 | 333.6 | 13,209.2 | 2.5 | Low |
| 10020002180 | 34.6 | 1,813.0 | 1.9 | Low |
| 10020002180 | 109.8 | 8,482.3 | 1.3 | Low |
| 10020003010 | 309.5 | 802.1 | 38.6 | Moderate |
| 10020003010 | 728.6 | 10,054.3 | 7.2 | Low |
| 10020003010 | 740.1 | 6,782.2 | 10.9 | Low |
| 10020003020 | 1,339.9 | 13,203.6 | 10.1 | Low |
| 10020003030 | 78.5 | 134.4 | 58.4 | High |
| 10020003040 | 1,503.1 | 10,305.2 | 14.6 | Low |
| 10020003040 | 905.6 | 4,574.0 | 19.8 | Low |
| 10020003050 | 1,224.2 | 8,816.9 | 13.9 | Low |
| 10020003050 | 257.5 | 260.8 | 98.7 | High |
| 10020003070 | 1,890.1 | 2,559.7 | 73.8 | High |
| 10020003070 | 98.4 | 119.7 | 82.2 | High |
| 10020003080 | 2,773.4 | 16,463.3 | 16.8 | Low |
| 10020003080 | 3,500.9 | 11,584.1 | 30.2 | Moderate |
| 10020003090 | 889.5 | 32,665.1 | 2.7 | Low |
| 10020003100 | 1,507.9 | 34,508.7 | 4.4 | Low |
| 10020003100 | 603.2 | 12,992.8 | 4.6 | Low |
| 10020003110 | 264.5 | 27,370.7 | 1.0 | Low |
| 10020003110 | 297.0 | 10,427.4 | 2.8 | Low |
| 10020003110 | 109.5 | 8,880.4 | 1.2 | Low |

| HUC6 Watershed | Acres with Incomplete Landscape Data | Total Acres | Percentage of Total Acres | Rating for missing data: low < 20%; mod 20-50%; high >50% |
|---|---|---|---|---|
| 17040207120 | 0.0 | 6,079.3 | 0.0 | Low |
| 17040207120 | 0.0 | 12,378.5 | 0.0 | Low |
| 17040207120 | 0.0 | 12,055.1 | 0.0 | Low |
| 17040207130 | 0.0 | 11,404.4 | 0.0 | Low |
| 17040207130 | 0.0 | 19,538.5 | 0.0 | Low |
| 17040207130 | 0.0 | 11,309.9 | 0.0 | Low |
| 17040214030 | 0.0 | 5,202.6 | 0.0 | Low |
| 17040214040 | 0.0 | 959.1 | 0.0 | Low |
| 17040214040 | 0.0 | 4,586.2 | 0.0 | Low |
| 17040214040 | 0.0 | 11,528.6 | 0.0 | Low |
| 17040214040 | 0.0 | 9,996.1 | 0.0 | Low |
| 17040214040 | 0.0 | 5,985.0 | 0.0 | Low |
| 17040214040 | 0.0 | 8,500.6 | 0.0 | Low |
| 17040214040 | 0.0 | 19,918.8 | 0.0 | Low |
| 17040214040 | 0.0 | 5,896.3 | 0.0 | Low |
| 17040214040 | 0.0 | 7,267.6 | 0.0 | Low |
| 17040214041 | 0.0 | 5,179.5 | 0.0 | Low |
| 17040214060 | 0.0 | 1,578.1 | 0.0 | Low |
| 17040214060 | 0.0 | 33,145.6 | 0.0 | Low |
| 17040214060 | 0.0 | 1,908.0 | 0.0 | Low |
| 17040214060 | 0.0 | 8,969.2 | 0.0 | Low |
| 17040214060 | 0.0 | 16,811.5 | 0.0 | Low |
| 17040214060 | 0.0 | 3,782.9 | 0.0 | Low |
| 17040215020 | 0.0 | 3,042.0 | 0.0 | Low |
| 17040215030 | 0.0 | 1,562.0 | 0.0 | Low |
| 17040215030 | 0.0 | 9,564.4 | 0.0 | Low |
| 17040215030 | 0.0 | 13,116.0 | 0.0 | Low |
| 17040215030 | 0.0 | 15,649.6 | 0.0 | Low |
| 17040215040 | 0.0 | 12,484.3 | 0.0 | Low |
| 17040215040 | 0.0 | 15,381.6 | 0.0 | Low |
| 17040215050 | 0.0 | 3,021.9 | 0.0 | Low |
| 17040215050 | 0.0 | 14,240.9 | 0.0 | Low |
| 17040215050 | 0.0 | 9,480.8 | 0.0 | Low |
| 17040215050 | 0.0 | 21,280.3 | 0.0 | Low |
| 17040215050 | 0.0 | 5,772.8 | 0.0 | Low |
| 17040215060 | 0.0 | 944.9 | 0.0 | Low |
| 17040215060 | 0.0 | 8,354.5 | 0.0 | Low |
| 17040215060 | 0.0 | 12,534.4 | 0.0 | Low |
| 17040216020 | 0.0 | 5,231.0 | 0.0 | Low |
| 17040216020 | 0.0 | 425.4 | 0.0 | Low |
| 17040216030 | 0.0 | 7,284.9 | 0.0 | Low |
| 17040216030 | 0.0 | 9,212.6 | 0.0 | Low |
| 17040216030 | 0.0 | 17,344.5 | 0.0 | Low |
| 17040216040 | 0.0 | 13,026.6 | 0.0 | Low |
| 17040216050 | 0.0 | 1,348.7 | 0.0 | Low |
| 17040216060 | 0.0 | 10,455.8 | 0.0 | Low |
| ***Statistics: Total*** | 545,167.3 | ***Total*** 13,505,540.8 | ***Average*** 3.9 | |

# GYA Watershed Vulnerability (GYA HUC6)

### Ratings for Watersheds or portions thereof in Federal ownership only.

Henry F. Shovic, Interagency Spatial Analysis Center

| HUC6 Watershed | Sensitive Lands (Acres) | Total Acres | Percentage of | Watershed Vulnerability Rating |
|---|---|---|---|---|
| 10020001010 | 1785.5 | 7006.3 | 25.5 | Moderate |
| 10020001010 | 724.3 | 5553.5 | 13.0 | Low |
| 10020001010 | 15.5 | 15.8 | 98.2 | High |
| 10020001010 | 882.5 | 1799.9 | 49.0 | Moderate |
| 10020001010 | 17.7 | 44.4 | 39.9 | Moderate |
| 10020001010 | 0.0 | 4.8 | 0.0 | Low |
| 10020001010 | 2820.6 | 3902.4 | 72.3 | High |
| 10020001010 | 11.3 | 16.5 | 68.7 | High |
| 10020001011 | 0.0 | 7.2 | 0.0 | Low |
| 10020001011 | 0.0 | 2.1 | 0.0 | Low |
| 10020001020 | 4590.9 | 16497.7 | 27.8 | Moderate |
| 10020001020 | 3566.5 | 5552.4 | 64.2 | High |
| 10020001020 | 1221.0 | 3707.6 | 32.9 | Moderate |
| 10020001020 | 0.0 | 9.5 | 0.0 | Low |
| 10020001020 | 4.3 | 4.9 | 87.4 | High |
| 10020002050 | 1771.1 | 8838.2 | 20.0 | Moderate |
| 10020002050 | 976.3 | 1860.1 | 52.5 | High |
| 10020002050 | 8673.5 | 15499.9 | 56.0 | High |
| 10020003010 | 13950.1 | 33318.4 | 41.9 | Moderate |
| 10020003010 | 13217.3 | 26393.1 | 50.1 | High |
| 10020003010 | 15428.6 | 26526.2 | 58.2 | High |
| 10020003010 | 17421.0 | 32780.2 | 53.1 | High |
| 10020003010 | 7628.9 | 14550.9 | 52.4 | High |
| 10020003010 | 3606.2 | 9402.3 | 38.4 | Moderate |
| 10020003010 | 3825.8 | 10059.7 | 38.0 | Moderate |
| 10020003010 | 333.5 | 3161.4 | 10.5 | Low |
| 10020003010 | 4363.1 | 12841.7 | 34.0 | Moderate |
| 10020003030 | 167.2 | 2898.5 | 5.8 | Low |
| 10020003030 | 82.9 | 1103.8 | 7.5 | Low |
| 10020003040 | 5.5 | 282.3 | 1.9 | Low |
| 10020003040 | 1207.5 | 3526.2 | 34.2 | Moderate |
| 10020003040 | 958.2 | 5620.7 | 17.0 | Low |
| 10020003050 | 998.4 | 4185.0 | 23.9 | Moderate |
| 10020003050 | 1919.3 | 9788.4 | 19.6 | Low |
| 10020003050 | 3024.5 | 12788.8 | 23.6 | Moderate |
| 10020003050 | 1928.5 | 7805.1 | 24.7 | Moderate |
| 10020003050 | 4596.9 | 11700.8 | 39.3 | Moderate |
| 10020005010 | 135.8 | 2802.7 | 4.8 | Low |
| 10020005010 | 6.3 | 895.7 | 0.7 | Low |
| 10020005050 | 21.8 | 64.2 | 33.9 | Moderate |
| 10020005050 | 0.0 | 25.8 | 0.0 | Low |
| 10020005060 | 870.2 | 21190.0 | 4.1 | Low |
| 10020005060 | 0.0 | 8818.4 | 0.0 | Low |

| HUC6 Watershed | Sensitive Lands (Acres) | Total Acres | Percentage of | Watershed Vulnerability Rating |
|---|---|---|---|---|
| 17040204010 | 3549.8 | 8844.4 | 40.1 | Moderate |
| 17040204020 | 4346.3 | 25700.5 | 16.9 | Low |
| 17040204020 | 2052.6 | 4478.3 | 45.8 | Moderate |
| 17040204020 | 2773.3 | 7316.8 | 37.9 | Moderate |
| 17040204020 | 0.0 | 52.7 | 0.0 | Low |
| 17040204020 | 956.8 | 8684.8 | 11.0 | Low |
| 17040204030 | 3224.5 | 12403.3 | 26.0 | Moderate |
| 17040204030 | 4003.7 | 11641.1 | 34.4 | Moderate |
| 17040204030 | 5867.7 | 15259.2 | 38.5 | Moderate |
| 17040204030 | 1180.8 | 1201.8 | 98.3 | High |
| 17040204030 | 993.3 | 1750.9 | 56.7 | High |
| 17040204030 | 571.3 | 7798.2 | 7.3 | Low |
| 17040204030 | 3690.3 | 8583.4 | 43.0 | Moderate |
| 17040204040 | 7047.2 | 22322.8 | 31.6 | Moderate |
| 17040204040 | 3441.3 | 11618.1 | 29.6 | Moderate |
| 17040204040 | 10130.2 | 13296.0 | 76.2 | High |
| 17040204040 | 6190.5 | 8595.0 | 72.0 | High |
| 17040204050 | 0.0 | 2174.3 | 0.0 | Low |
| 17040204050 | 0.0 | 1247.7 | 0.0 | Low |
| 17040204060 | 5484.9 | 13748.9 | 39.9 | Moderate |
| 17040204060 | 638.2 | 638.6 | 99.9 | High |
| 17040204060 | 110.3 | 11996.2 | 0.9 | Low |
| 17040204070 | 15709.7 | 16040.4 | 97.9 | High |
| 17040204070 | 619.4 | 632.4 | 98.0 | High |
| ***Statistics:*** | ***Total*** 4,362,629.8 | ***Total*** 12,609,211.0 | ***Average*** 34.2 | |

# GYA Landscape Data Completeness (GYA HUC6)

***Ratings for HUC6 Watersheds or portions thereof in Federal ownership only.***
***Henry F. Shovic, Interagency Spatial Analysis Center***

| HUC6 Watershed | Acres with Incomplete Landscape Data | Total Acres | Percentage of Total Acres | Rating for missing data: low < 20%; mod 20-50%; high >50% |
|---|---|---|---|---|
| 10020001010 | 585.5 | 7,006.3 | 8.4 | Low |
| 10020001010 | 1,463.3 | 5,553.5 | 26.3 | Moderate |
| 10020001010 | 0.0 | 15.8 | 0.0 | Low |
| 10020001010 | 0.0 | 1,799.9 | 0.0 | Low |
| 10020001010 | 0.0 | 44.4 | 0.0 | Low |
| 10020001010 | 0.0 | 4.8 | 0.0 | Low |
| 10020001010 | 32.6 | 3,902.4 | 0.8 | Low |
| 10020001010 | 0.0 | 16.5 | 0.0 | Low |
| 10020001011 | 0.0 | 7.2 | 0.0 | Low |
| 10020001011 | 0.0 | 2.1 | 0.0 | Low |
| 10020001020 | 141.0 | 16,497.7 | 0.9 | Low |
| 10020001020 | 217.5 | 5,552.4 | 3.9 | Low |
| 10020001020 | 183.9 | 3,707.6 | 5.0 | Low |
| 10020001020 | 0.0 | 9.5 | 0.0 | Low |
| 10020001020 | 0.0 | 4.9 | 0.0 | Low |
| 10020002050 | 96.1 | 8,838.2 | 1.1 | Low |
| 10020002050 | 41.6 | 1,860.1 | 2.2 | Low |
| 10020002050 | 384.4 | 15,499.9 | 2.5 | Low |
| 10020003010 | 375.6 | 33,318.4 | 1.1 | Low |
| 10020003010 | 966.4 | 26,393.1 | 3.7 | Low |
| 10020003010 | 1,146.8 | 26,526.2 | 4.3 | Low |
| 10020003010 | 868.8 | 32,780.2 | 2.7 | Low |
| 10020003010 | 227.5 | 14,550.9 | 1.6 | Low |
| 10020003010 | 1,636.8 | 9,402.3 | 17.4 | Low |
| 10020003010 | 2,320.2 | 10,059.7 | 23.1 | Moderate |
| 10020003010 | 1,509.3 | 3,161.4 | 47.7 | Moderate |
| 10020003010 | 1,712.3 | 12,841.7 | 13.3 | Low |
| 10020003030 | 2,383.7 | 2,898.5 | 82.2 | High |
| 10020003030 | 886.4 | 1,103.8 | 80.3 | High |
| 10020003040 | 275.2 | 282.3 | 97.5 | High |
| 10020003040 | 321.9 | 3,526.2 | 9.1 | Low |
| 10020003040 | 841.0 | 5,620.7 | 15.0 | Low |
| 10020003050 | 930.4 | 4,185.0 | 22.2 | Moderate |
| 10020003050 | 1,566.6 | 9,788.4 | 16.0 | Low |
| 10020003050 | 1,125.0 | 12,788.8 | 8.8 | Low |
| 10020003050 | 1,054.7 | 7,805.1 | 13.5 | Low |
| 10020003050 | 1,034.3 | 11,700.8 | 8.8 | Low |
| 10020005010 | 767.4 | 2,802.7 | 27.4 | Moderate |
| 10020005010 | 669.1 | 895.7 | 74.7 | High |
| 10020005050 | 20.7 | 64.2 | 32.2 | Moderate |
| 10020005050 | 21.7 | 25.8 | 84.2 | High |
| 10020005060 | 1,939.1 | 21,190.0 | 9.2 | Low |
| 10020005060 | 1,464.3 | 8,818.4 | 16.6 | Low |
| 10020005060 | 828.3 | 1,758.0 | 47.1 | Moderate |

| HUC6 Watershed | Acres with Incomplete Landscape Data | Total Acres | Percentage of Total Acres | Rating for missing data: low < 20%; mod 20-50%; high >50% |
|---|---|---|---|---|
| 17040105030 | 0.0 | 12,482.0 | 0.0 | Low |
| 17040105030 | 0.0 | 6,950.5 | 0.0 | Low |
| 17040105030 | 0.0 | 28,866.9 | 0.0 | Low |
| 17040105030 | 0.0 | 15,082.1 | 0.0 | Low |
| 17040203010 | 18.8 | 28,237.5 | 0.1 | Low |
| 17040203010 | 0.0 | 11,343.9 | 0.0 | Low |
| 17040203010 | 63.8 | 15,214.0 | 0.4 | Low |
| 17040203010 | 57.2 | 44,857.3 | 0.1 | Low |
| 17040203020 | 0.0 | 26,444.3 | 0.0 | Low |
| 17040203020 | 672.3 | 34,534.8 | 1.9 | Low |
| 17040203020 | 0.0 | 28,714.9 | 0.0 | Low |
| 17040203020 | 14.0 | 18,298.0 | 0.1 | Low |
| 17040203030 | 0.0 | 22,825.2 | 0.0 | Low |
| 17040203030 | 0.0 | 6,132.1 | 0.0 | Low |
| 17040203030 | 203.3 | 11,840.7 | 1.7 | Low |
| 17040204010 | 3.7 | 16,880.3 | 0.0 | Low |
| 17040204010 | 0.0 | 13,891.3 | 0.0 | Low |
| 17040204010 | 0.0 | 8,361.3 | 0.0 | Low |
| 17040204010 | 0.0 | 8,148.7 | 0.0 | Low |
| 17040204010 | 0.0 | 14,452.2 | 0.0 | Low |
| 17040204010 | 0.0 | 1,945.0 | 0.0 | Low |
| 17040204010 | 0.0 | 6,699.9 | 0.0 | Low |
| 17040204010 | 0.0 | 8,844.4 | 0.0 | Low |
| 17040204020 | 0.0 | 25,700.5 | 0.0 | Low |
| 17040204020 | 0.0 | 4,478.3 | 0.0 | Low |
| 17040204020 | 0.0 | 7,316.8 | 0.0 | Low |
| 17040204020 | 0.0 | 52.7 | 0.0 | Low |
| 17040204020 | 0.0 | 8,684.8 | 0.0 | Low |
| 17040204030 | 0.0 | 12,403.3 | 0.0 | Low |
| 17040204030 | 0.0 | 11,641.1 | 0.0 | Low |
| 17040204030 | 0.0 | 15,259.2 | 0.0 | Low |
| 17040204030 | 0.0 | 1,201.8 | 0.0 | Low |
| 17040204030 | 0.0 | 1,750.9 | 0.0 | Low |
| 17040204030 | 0.0 | 7,798.2 | 0.0 | Low |
| 17040204030 | 0.0 | 8,583.4 | 0.0 | Low |
| 17040204040 | 0.0 | 22,322.8 | 0.0 | Low |
| 17040204040 | 0.0 | 11,618.1 | 0.0 | Low |
| 17040204040 | 0.0 | 13,296.0 | 0.0 | Low |
| 17040204040 | 0.0 | 8,595.0 | 0.0 | Low |
| 17040204050 | 0.0 | 2,174.3 | 0.0 | Low |
| 17040204050 | 0.0 | 1,247.7 | 0.0 | Low |
| 17040204060 | 0.0 | 13,748.9 | 0.0 | Low |
| 17040204060 | 0.0 | 638.6 | 0.0 | Low |
| 17040204060 | 0.0 | 11,996.2 | 0.0 | Low |
| 17040204070 | 0.0 | 16,040.4 | 0.0 | Low |
| 17040204070 | 0.0 | 632.4 | 0.0 | Low |

***Statistics: Total*** 543,582.7 ***Total*** 12,609,211.0 ***Average*** 5.2

## Appendix Four: IWWI HUC6 Watersheds Having "High" No Data Status

| GYA HUC6 Watershed | Acres with No Data | Total Acres | Primary Unit |
|---|---|---|---|
| 100200030301 | 78.5 | 134.351156 | Beaverhead-Deerlodge N. F. |
| 100200030503 | 257.5 | 260.806541 | Beaverhead-Deerlodge N. F. |
| 100200030701 | 1,890 | 2,560 | Beaverhead-Deerlodge N. F. |
| 100200030702 | 98 | 120 | Beaverhead-Deerlodge N. F. |
| 100200050504 | 675 | 1,155 | Beaverhead-Deerlodge N. F. |
| 100200070602 | 4,967 | 8,949 | Beaverhead-Deerlodge N. F. |
| 100200070603 | 251 | 291 | Beaverhead-Deerlodge N. F. |
| 100200070701 | 31,654 | 33,037 | Beaverhead-Deerlodge N. F. |
| 100200070801 | 1,864 | 1,865 | Beaverhead-Deerlodge N. F. |
| 100200070802 | 9,751 | 9,821 | Beaverhead-Deerlodge N. F. |
| 100200070903 | 10 | 10 | Beaverhead-Deerlodge N. F. |
| 100200071001 | 9,634 | 9,636 | Beaverhead-Deerlodge N. F. |
| 100200071002 | 14,799 | 17,306 | Beaverhead-Deerlodge N. F. |
| 100200071102 | 863 | 1,223 | Beaverhead-Deerlodge N. F. |
| 100200071202 | 20,608 | 21,105 | Beaverhead-Deerlodge N. F. |
| 100200072701 | 280 | 460 | Beaverhead-Deerlodge N. F. |
| 10070001002009 | 83,379 | 84,446 | Yellowstone National Park |
| 170401030101 | 16,702 | 23,602 | Bridger Teton N. F. |
| 170401030106 | 5,820 | 9,222 | Bridger Teton N. F. |
| 170401030107 | 8,320 | 8,733 | Bridger Teton N. F. |
| 170401030108 | 10,749 | 17,281 | Bridger Teton N. F. |
| 170401030203 | 4,252 | 6,484 | Bridger Teton N. F. |
| 170401030301 | 3,924 | 6,724 | Bridger Teton N. F. |
| 100800030105 | 522 | 522 | Shoshone N. F. |
| 100800020302 | 17 | 17 | Shoshone N. F. |
| 100800030102 | 14,515 | 14,515 | Shoshone N. F. |
| 100800020202 | 431 | 431 | Shoshone N. F. |
| 100800020201 | 17,993 | 17,993 | Shoshone N. F. |
| 100800030104 | 5,336 | 5,336 | Shoshone N. F. |
| 100800030101 | 28,501 | 28,501 | Shoshone N. F. |
| 100800030103 | 7,824 | 7,824 | Shoshone N. F. |
| 100800030209 | 5,035 | 5,035 | Shoshone N. F. |
| 100800030208 | 4,811 | 4,811 | Shoshone N. F. |
| 100800030207 | 1,551 | 1,551 | Shoshone N. F. |
| 100800030203 | 8,809 | 8,809 | Shoshone N. F. |
| 100800030201 | 23,744 | 23,744 | Shoshone N. F. |
| 100800030206 | 5,225 | 5,225 | Shoshone N. F. |
| 100800030205 | 17,052 | 17,052 | Shoshone N. F. |
| 100800030202 | 6,956 | 6,956 | Shoshone N. F. |
| 100800030204 | 9,958 | 9,958 | Shoshone N. F. |
| 100800030316 | 2,555 | 2,555 | Shoshone N. F. |
| 100800030305 | 7,814 | 7,814 | Shoshone N. F. |

| | | | |
|---|---|---|---|
| 100800030303 | 5,971 | 5,971 | Shoshone N. F. |
| 100800030306 | 4,965 | 4,965 | Shoshone N. F. |
| 100800030301 | 20,142 | 20,142 | Shoshone N. F. |
| 100800030304 | 5,089 | 5,089 | Shoshone N. F. |
| 100800030302 | 8,166 | 8,166 | Shoshone N. F. |
| 100800020701 | 6,232 | 6,232 | Shoshone N. F. |
| 100800030308 | 463 | 463 | Shoshone N. F. |
| 101800060209 | 13,383 | 13,383 | Shoshone N. F. |
| 101800060208 | 8,659 | 8,659 | Shoshone N. F. |
| 101800060203 | 2,737 | 2,737 | Shoshone N. F. |
| 101800060109 | 2,921 | 2,921 | Shoshone N. F. |
| | 478,202 | 511,801 | |

| | | |
|---|---|---|
| Beaverhead-Deerlodge N. F. | 107,933 | |
| Yellowstone National Park | 84,446 | Yellowstone Lake |
| Bridger Teton N. F. | 72,046 | |
| Shoshone N. F. | 247,376 | |
| | 511,801 | |

# Appendix Five: GYA HUC6 Watersheds Having "High" No Data Status

| GYA HUC6 Watershed | Acres with No Data | Total Acres | Primary Unit |
|---|---|---|---|
| 100200030302 | 2,384 | 2,899 | Beaverhead-Deerlodge N. F. |
| 100200030303 | 886 | 1,104 | Beaverhead-Deerlodge N. F. |
| 100200030401 | 275 | 282 | Beaverhead-Deerlodge N. F. |
| 100200050103 | 669 | 896 | Beaverhead-Deerlodge N. F. |
| 100200050502 | 22 | 26 | Beaverhead-Deerlodge N. F. |
| 100200071009 | 24,089 | 31,816 | Beaverhead-Deerlodge N. F. |
| 100200071104 | 665 | 1,007 | Beaverhead-Deerlodge N. F. |
| 100200071201 | 5,621 | 5,642 | Beaverhead-Deerlodge N. F. |
| 100200071202 | 11,376 | 11,694 | Beaverhead-Deerlodge N. F. |
| 100200071203 | 9,088 | 9,818 | Beaverhead-Deerlodge N. F. |
| 100200071204 | 5,493 | 5,592 | Beaverhead-Deerlodge N. F. |
| 100200071205 | 909 | 910 | Beaverhead-Deerlodge N. F. |
| 100200071301 | 12,996 | 15,330 | Beaverhead-Deerlodge N. F. |
| 100200071302 | 1,795 | 1,795 | Beaverhead-Deerlodge N. F. |
| 100200071303 | 9,984 | 9,996 | Beaverhead-Deerlodge N. F. |
| 100200071304 | 9,332 | 9,334 | Beaverhead-Deerlodge N. F. |
| 100200071305 | 2,012 | 2,013 | Beaverhead-Deerlodge N. F. |
| 100200071306 | 428 | 697 | Beaverhead-Deerlodge N. F. |
| 100200071401 | 3,535 | 6,215 | Beaverhead-Deerlodge N. F. |
| 170401030107 | 19,313 | 29,993 | Bridger Teton N. F. |
| 170401030109 | 16,554 | 23,105 | Bridger Teton N. F. |
| 100800020101 | 18,402 | 18,402 | Shoshone N. F. |
| 100800030204 | 522 | 522 | Shoshone N. F. |
| 100800030203 | 14,516 | 14,516 | Shoshone N. F. |
| 100800030202 | 12,873 | 12,873 | Shoshone N. F. |
| 100800030210 | 5,051 | 5,051 | Shoshone N. F. |
| 100800030207 | 6,774 | 6,774 | Shoshone N. F. |
| 100800030201 | 28,768 | 28,768 | Shoshone N. F. |
| 100800030209 | 4,796 | 4,796 | Shoshone N. F. |
| 100800030109 | 2,573 | 2,573 | Shoshone N. F. |
| 100800030206 | 18,787 | 18,787 | Shoshone N. F. |
| 100800030205 | 30,670 | 30,670 | Shoshone N. F. |
| 100800030208 | 17,064 | 17,064 | Shoshone N. F. |
| 100800030102 | 18,871 | 18,871 | Shoshone N. F. |
| 100800030103 | 4,983 | 4,983 | Shoshone N. F. |
| 100800030101 | 28,263 | 28,263 | Shoshone N. F. |
| 100800030105 | 466 | 466 | Shoshone N. F. |
| 100800020301 | 6,225 | 6,225 | Shoshone N. F. |
| 101800060206 | 13,390 | 13,390 | Shoshone N. F. |
| 101800060103 | 2,922 | 2,922 | Shoshone N. F. |
| 101800060205 | 8,666 | 8,666 | Shoshone N. F. |
| 101800060202 | 2,737 | 2,737 | Shoshone N. F. |

| | | |
|---|---|---|
| Total Area | 384,744 | 417,484 |
| | | |
| Beaverhead-Deerlodge N. F. | | 117,066 |
| Bridger Teton N. F. | | 53,099 |
| Shoshone N. F. | | 247,319 |

## Appendix Six. List of Data and Documents on the publication CD

- The GYA Landscape model report and data: in the folder GYA_LANDSCAPE_MODEL This data does not have the additions used in the present study.
- This report: in MS WORD format: GYA_Watershed_Vulnerability_ Report 030602.doc
- This report in Adobe Illustrator PDF format: GYA_Watershed_Vulnerability_ Report 030602.pdf
- A zip file of ACCESS databases containing all queries and tables used in this study: Appendix Two lists queries used in this study, and the database in which each is contained. Links between these databases must be updated before use. The zip file is called vulnerability_databases.zip
    - gyaHuc6_and_gyajoindiss summaries.mdb applied to the GYA watershed coverage
    - iwwiHuc6_and_gyajoindiss summaries.mdb applied to the older IWWI watershed coverage
    - gyavulnmaps.mdb final tables used in the maps in the final report. These are extracted from results calculated in the above two databases.
    - iwwi.mdb vulnerability data directly from the IWWI study
    - bvnf_csnf_cbnfsoil_data.mdb gya landscape model attribute data and VISUAL BASIC programs for calculating erodibility
- Four reports in MS WORD format: These are exemplified in Appendix Three, but are presented here in complete form.
    - Acres with No Soil Data by HUC6 Watershed.rtf
    - iwwi Acres with No Soil Data by HUC6 Watershed.rtf
    - iwwi Vulnerability by HUC6 Watershed.rtf
    - Vulnerability by HUC6 Watershed.rtf

- Arcview 3.2 projects including specifications for all maps used in this study

    - gyavulnerabilityproject110101.apr
    - iwwished8x11.apr

No attempt was made to preserve paths or coverage names in these projects.

Spatial Data used in this study are in UTM zone 12 meters NAD27

- The GYA modified landscape model coverage

This was modified from the original landscape model as indicated in this report: This is an ARC/INFO coverage called gyaiwwijoin. Its metadata is called gyaiwwijoinmeta.html

- The IWWI watershed coverages

The IWWI watershed coverage is in two formats. The first is a shapefile called iwwi_huc6.shp. It has not been edgematched but is of sufficient accuracy for use in display. It is not usable in analysis.

The second format is the original unit ARC/INFO coverages received from the IWWI project managers. These are in a folder called iwwi_huc6_data. No metadata was forwarded with these coverages. More information is in the report.

- The GYA watershed coverages

The base GYA coverage is in shapefile format (gya_huc6.shp). We compiled this coverage (termed GYA Watersheds in the report) from watershed data developed in 2001 by federal and state administrative units. We appended and edgematched these data. There are some data gaps, notably in the western part of the Caribou-Targhee National Forest. This is because data were in process of completion and not ready at time of publication. We clipped this coverage by the federal lands boundaries for the GYA, resulting in the two shapefiles shown below.

gya_huc6_fed_lands_only.shp This is a shapefile for the majority of the federal lands in the GYA.

shnf_clippe_gya_huc6.shp This is a shapefile for the southeastern part of the Shoshone National Forest.

- The GYA stream dissection coverage

This shapefile (highdiss111401dissolved.shp) was created by us for the GYA. It is at a scale of 1:100,000. Methods are given in the report. It was digitized on screen with a general line accuracy of 30 meters.