VALIDITY AND EFFECTIVENESS OF LANDSLIDE SUSCEPTIBILITY MAPS

FROM EVALUATION OF THE CINCINNATI, OHIO AREA

Question:

Do landslide susceptibility maps, developed from a landslide inventory and statistical analysis, reliably predict the future location of landslides?

Importance of this Question

- The popularity of landslide susceptibility maps (LSM) is increasing due to the capabilities of GIS software.
- These maps are often perceived as scientific fact.
- The reliability of such maps to predict the future location of landslides over an extended period of time has not been examined.

Primary Contributions

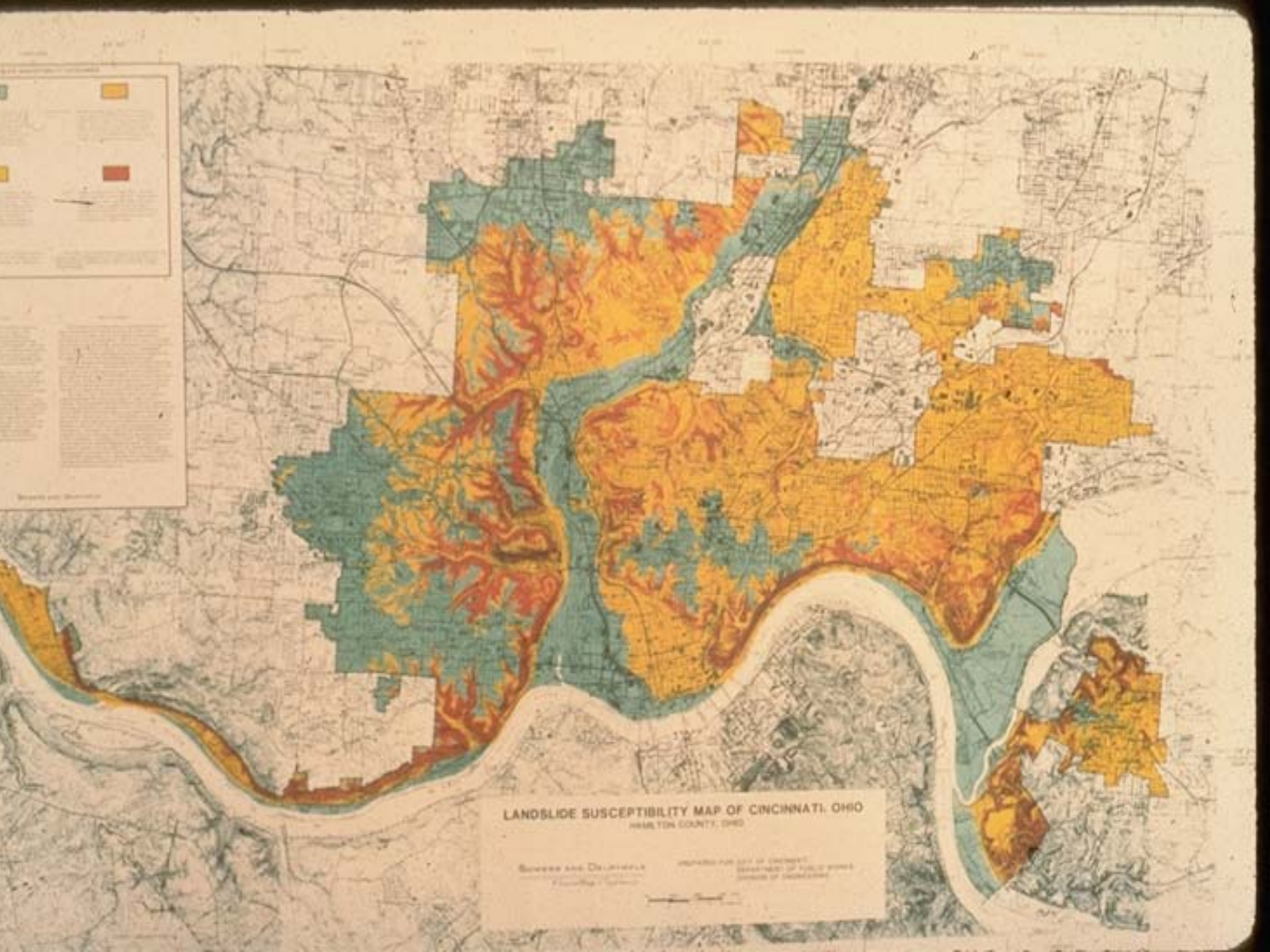
- Establish the validity of LSM for determining the potential for a landslide occurrence.
- Determine the effectiveness of using LSM in reducing landslide hazards.
- Develop methodology to inventory, store and track information and costs associated with landslides.

Secondary Contributions

- Inventory of landslides with City of Cincinnati and Anderson Township
- GIS data base to store landslide inventory.
- GIS based information for geologic data
- Assessment of cost of landslide damage.
- New LSM for City? County?
- Inventory used in further research.

Proposed Models

- Landslide Susceptibility Map of Cincinnati, Ohio
- Hillside Development Districts, Anderson Township
- Landslide Susceptibility Zones (CAGIS)
- UC Landslides Studies
- Landslide Susceptibility Map for N. Ky.


LANDSLIDE SUSCEPTIBILITY MAP OF CINCINNATI, OHIO
HAMILTON COUNTY, OHIO

LANDSLIDE SUSCEPTIBILITY CATEGORIES

LOW - Areas least susceptible to landsliding. Slopes generally less than 10% in areas of stable soil. These areas should not be affected by landsliding unless there is extensive human disturbance or unless adjacent areas of higher susceptibility encroach into or undercut this relatively stable area. These areas usually require a low level of geotechnical investigation.

MODERATELY HIGH - Moderately high susceptibility to landsliding. Slopes greater than 20% in areas of moderately stable soils, or slopes 10-20% in less stable soil types. These areas thus classified are often affected by landsliding due to human disturbance or natural processes. These areas require a high level of geotechnical investigation.

MODERATE - Moderate susceptibility to landsliding. Slopes generally 10-20% in areas of stable soil, or slopes less than 10% on less stable soil type. These areas thus classified may be affected by landsliding if human disturbance increases or loads the slopes or otherwise alters the original environmental setting. These areas require a moderate level of geotechnical investigation.

HIGH - Higher susceptibility to landsliding. All slopes greater than 20% in unstable soils. Slopes which appear to be stable may slide with only minor changes in angle, support at toe, drainage, or groundwater conditions. Extensive geotechnical investigations and proper design are necessary for development of these areas.

The susceptibility of a specific location on the map is based on conditions of slope, soil, and geology prior to alteration by man. Potential excavation, filling or drainage changes may affect these susceptibility classifications.

This map is not intended for private use by any person for any purpose, and Sowers and Dalrymple Consulting Engineers disclaim any responsibility for reliance by third parties on the information contained herein.

Scale 1: 249,340

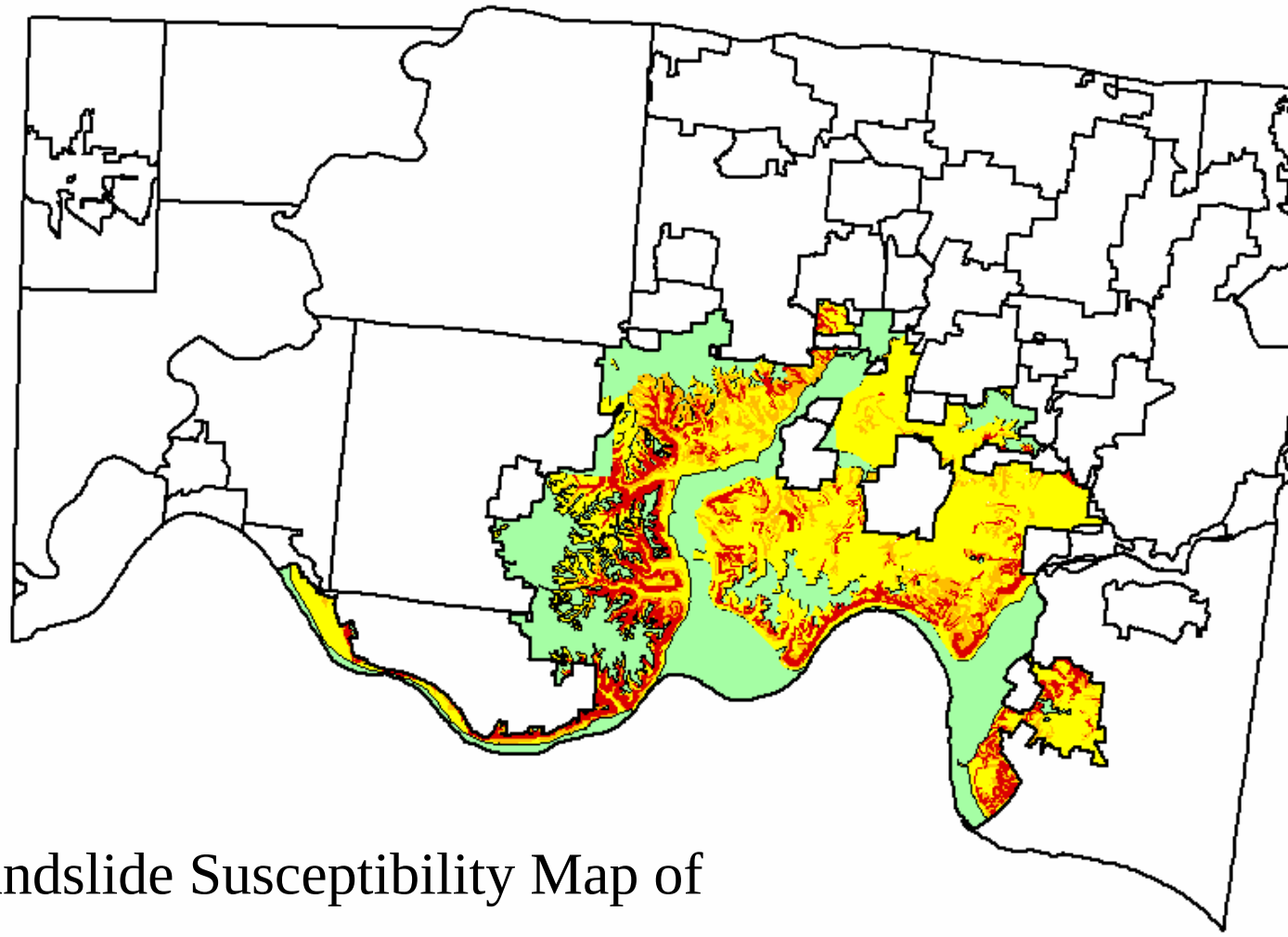
Local View

UmC
Uo
UrB
Ux
W
Wa
WbA
WeA
WhA
XfA
XfB2
int

Landslide.shp
Outside
Low
Moderate
Moderately High
High

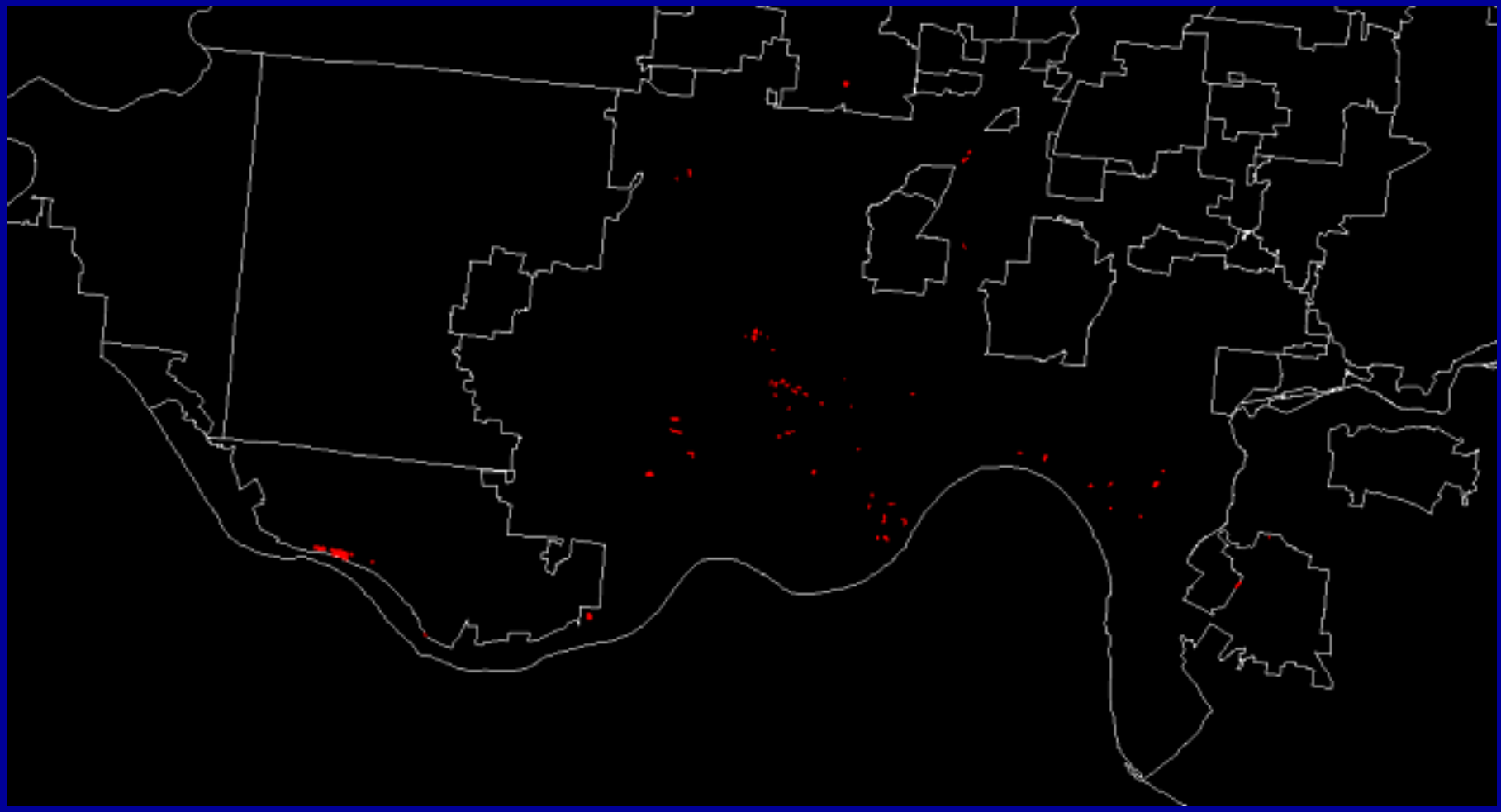
Geology_poly.shp
ARNHEIM FORMATION
BELLEVUE MEMBER
FAIRVIEW FORMATION
GRANT LAKE FORMATION
KOPE FORMATION
MIAMITOWN SHALE-FAIRV
POINT PLEASANT FORMA
WAYNESVILLE FORMATIO
WAYNESVILLE FORMATIO

REGIONAL COUNTY BOUNDARI



Landslide Susceptibility Map of Cincinnati, Ohio 1980 S&D

Landslide Locations from Sowers & Dalrymple



Cincinnati Landslide Variables
Sowers & Dalrymple

Variable	Relative Importance
Kope and Fairview (geology)	5.42
Eden, flaggy/Pate (soil)	3.45
Miamitown and Fairview (geology)	1.92
Kope and Quaternary (geology)	1.51
Eden (soil)	1.06
Eden – Urban (soil)	0.92
Urban – Martinsville (soil)	0.89
Quaternary (geology)	0.82
Kope (geology)	0.77
Eden, flaggy/Pate – Urban (soil)	0.71

Scale 1: 249,340

Local View

Collector Roads
Local Streets
Highway Ramps

200 Scale Grid

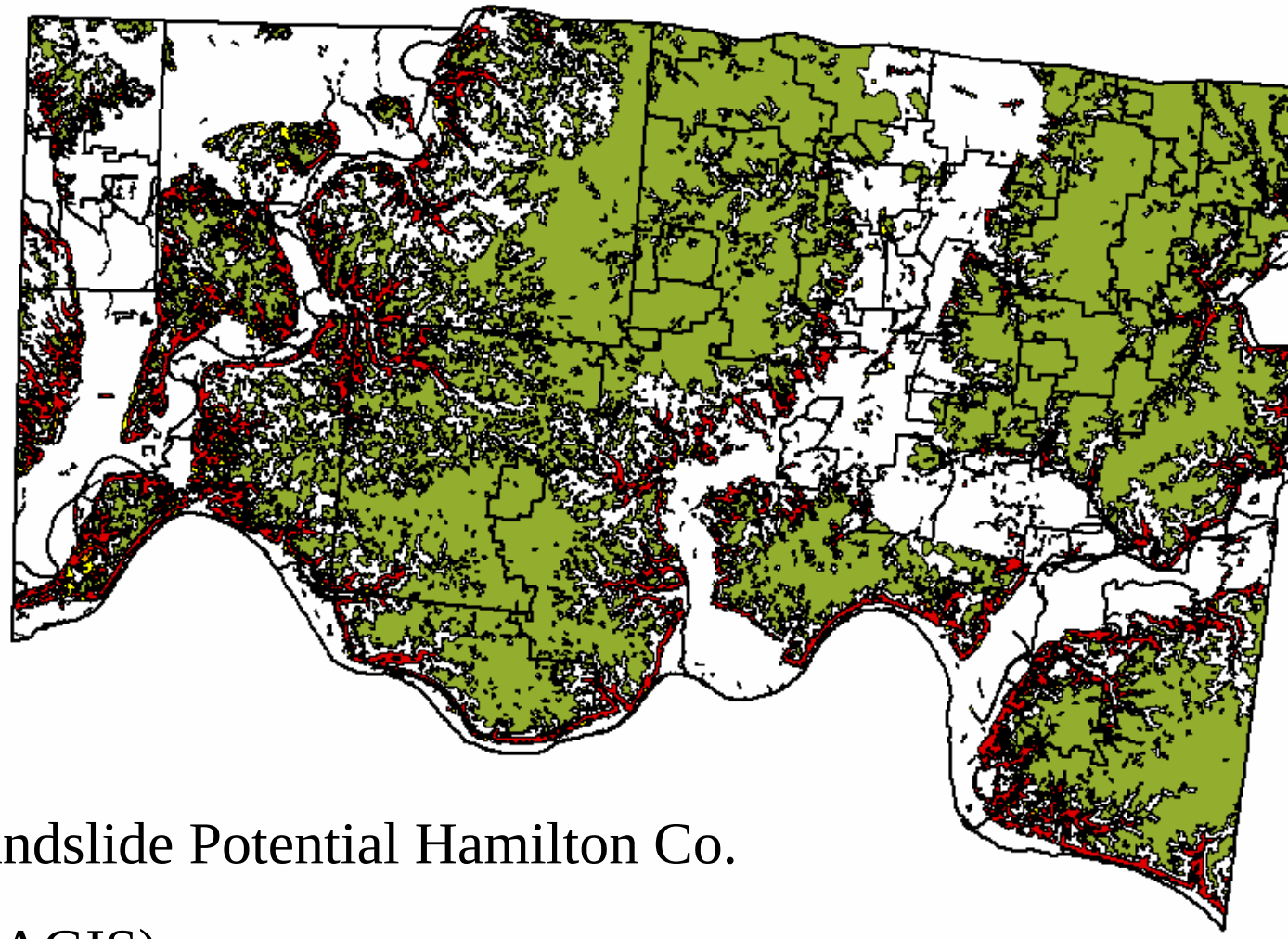
100 Scale Grid

Drainage Basins

LandSlide Potential
HIGH
LOW
M. HIGH
MODERATE
VERY HIGH

Pavement

Soils
ArA
ArB2
ArC2
AsB
AsC
AvA
AwA
BoD
BoE
BoF
CcC2
CdD
CdE
CdF
CnB2
CnC2
DaB
Dam



Landslide Potential Hamilton Co.

(CAGIS)

Parameters for Hamilton Co. Landslide Potential

As Shown in CAGIS

GEOLOGY		% SLOPE			
Formation	Elevation	< 10	11 to 20	21 to 30	> 30
Other	Above Elev. 680	Low	Moderate	Moderately High	High
Kope	Below Elev. 680	Moderate	Moderately High	High	Very High

Scale 1: 249,340

Local View

Collector Roads
Local Streets
Highway Ramps

200 Scale Grid

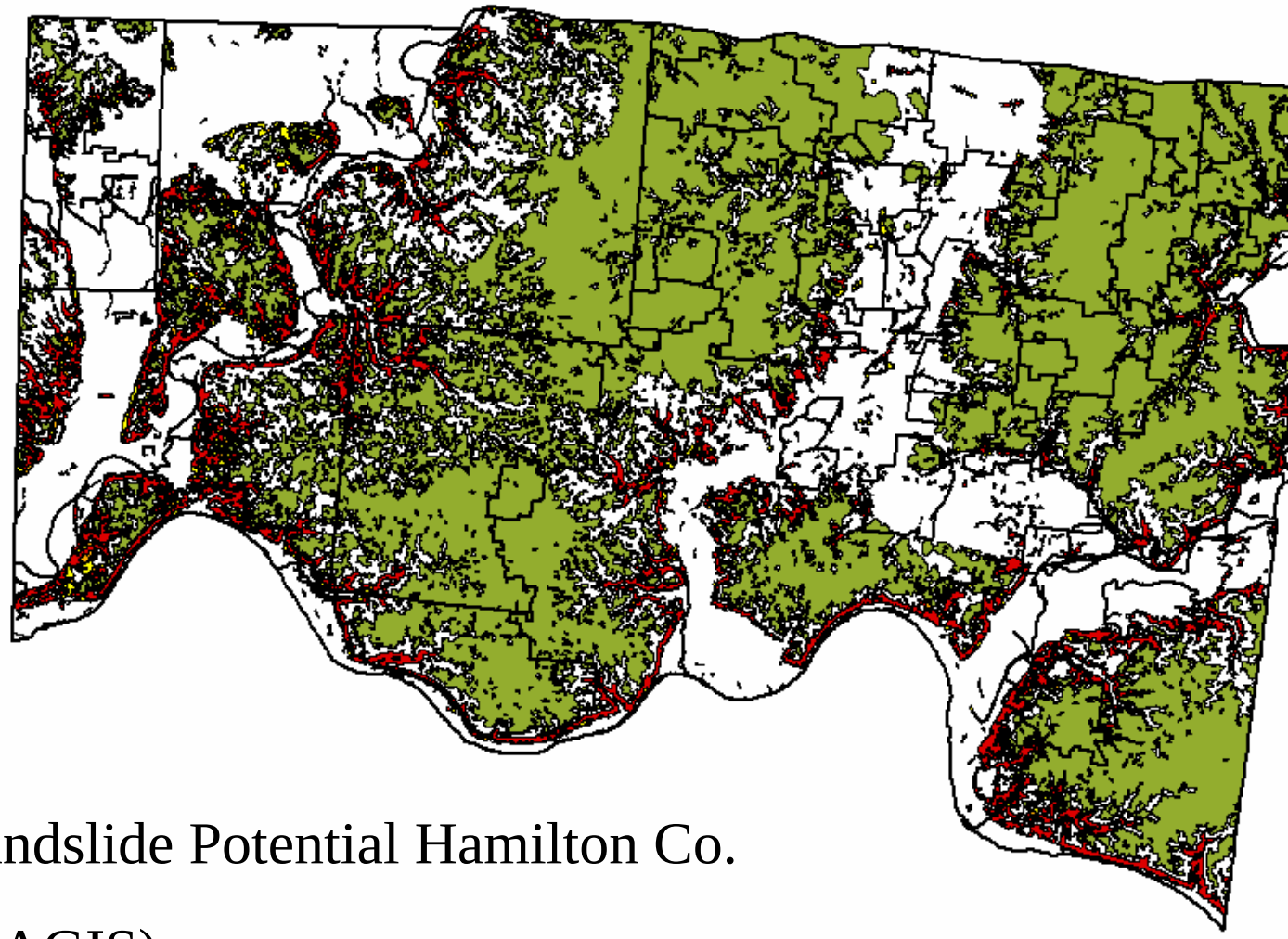
100 Scale Grid

Drainage Basins

LandSlide Potential
HIGH
LOW
M. HIGH
MODERATE
VERY HIGH

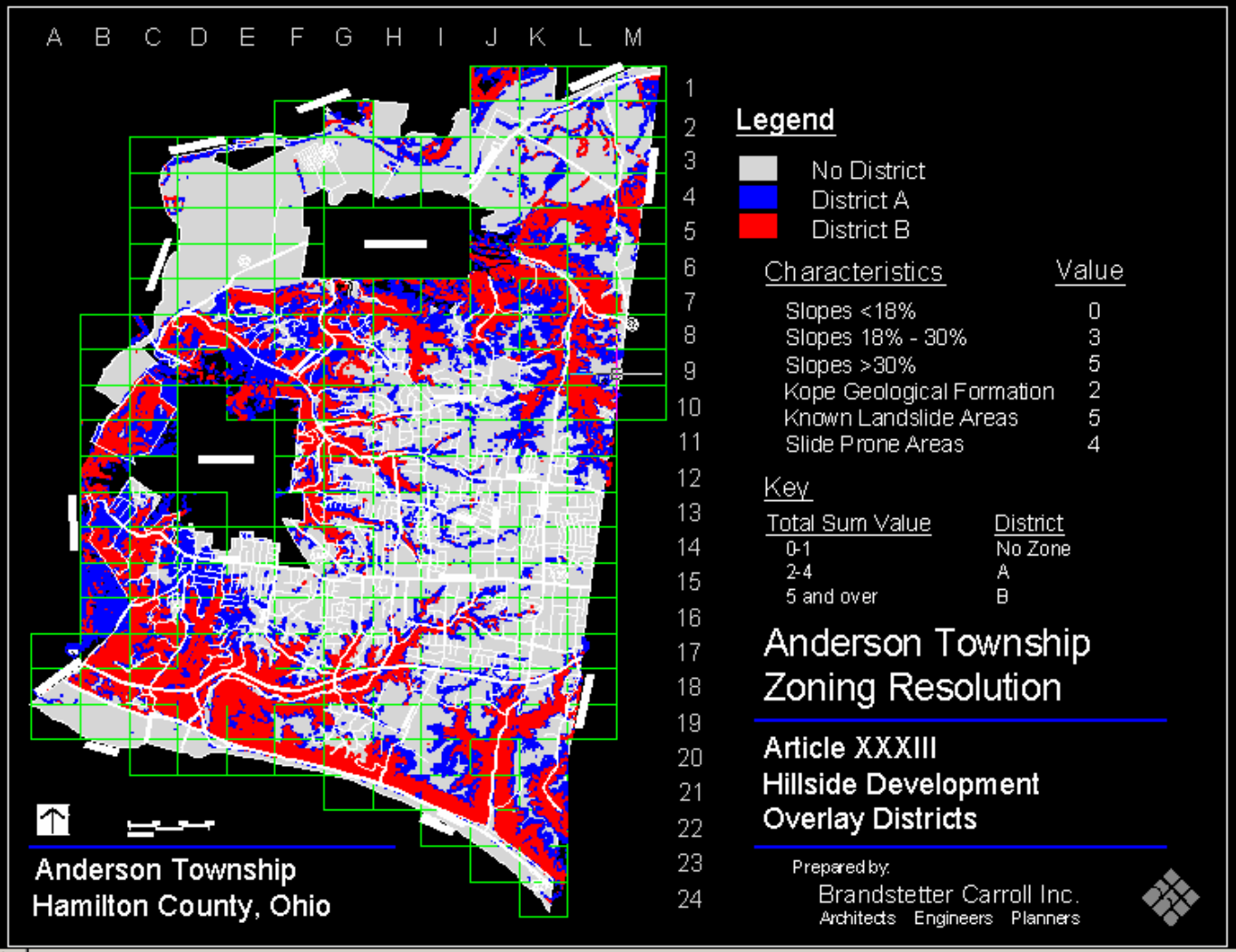
Pavement

Soils
ArA
ArB2
ArC2
AsB
AsC
AvA
AwA
BoD
BoE
BoF
CcC2
CdD
CdE
CdF
CnB2
CnC2
DaB
Dam



Landslide Potential Hamilton Co.

(CAGIS)


A B C D E F G H I J K L M
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Legend
No District
District A
District B
Characteristics
Value
Slopes <18%
0
Slopes 18% - 30%
3
Slopes >30%
5
Kope Geological Formation
2
Known Landslide Areas
5
Slide Prone Areas
4
Key
Total Sum Value
District
0-1
No Zone
2-4
A
5 and over
B
Anderson Township
Zoning Resolution
Article XXXIII
Hillside Development
Overlay Districts
Prepared by:
Brandstetter Carroll Inc.
Architects Engineers Planners
Anderson Township
Hamilton County, Ohio

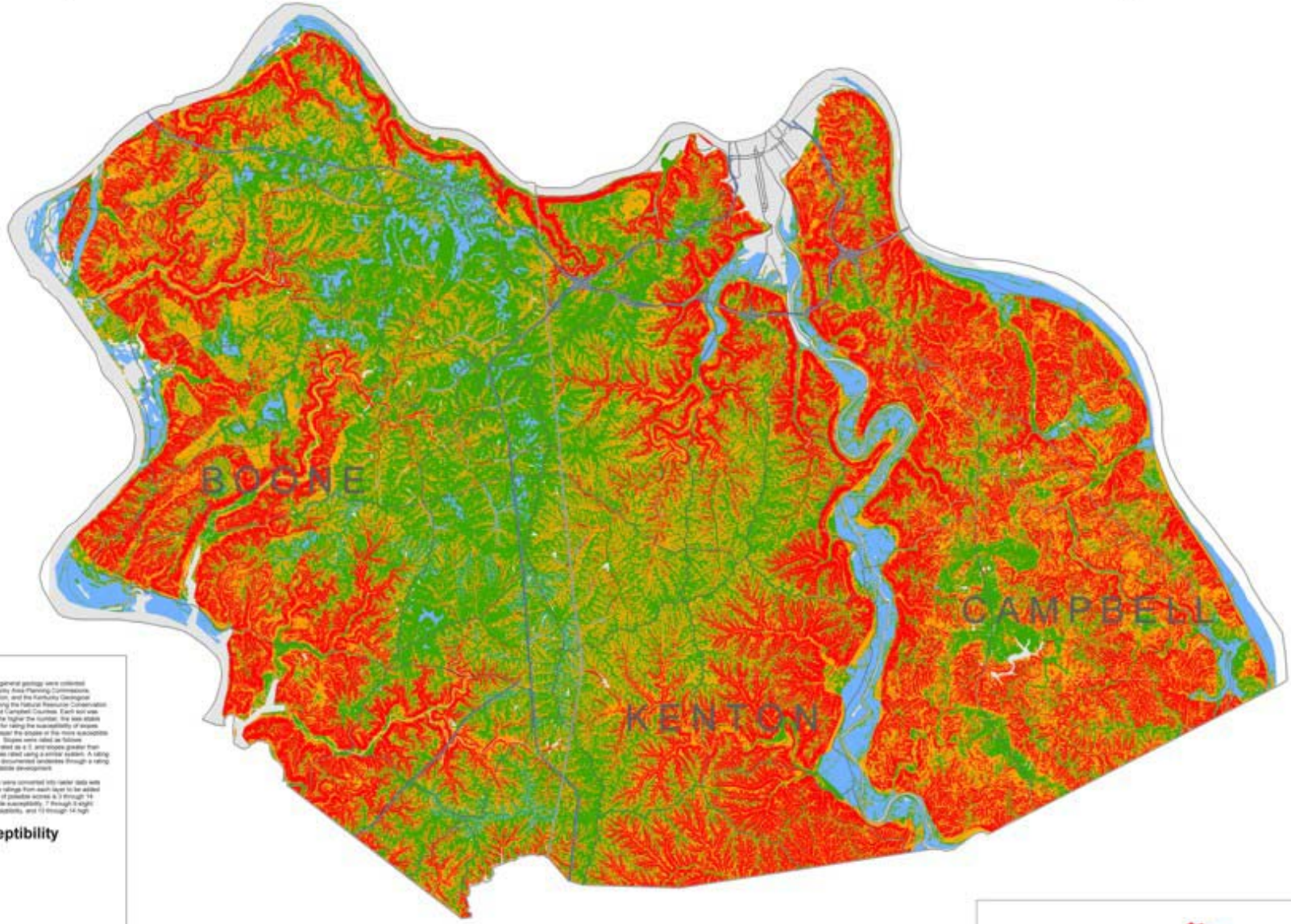
Parameters for Anderson Township Hillside Development Overlay Districts

Characteristics	Value
Slopes < 18%	0
Slopes 18% to 30%	3
Slopes > 30%	5
Kope Fm.	2
Known Landslide Areas	5
Slide Prone Soil	4

Key

Total Sum Value	District
0 - 1	No Zone
2 – 4	A
5 and Over	B

Northern Kentucky Landslide Documentation Investigation



METHODS

GIS vector data, including soils, slope, and general geology were collected from the Boone County and Northern Kentucky Area Planning Commissions, the Kentucky Office of Geographic Information, and the Kentucky Geological Survey. Soil stability data were classified using the Natural Resource Conservation Service Soil Surveys for Boone, Kenton, and Campbell Counties. Each soil was rated 1 through 4 according to its stability, the higher the number, the less stable the soil. The same process was carried out for rating the susceptibility of slopes and bedrock lithology. In each case, the steeper the slopes or the more susceptible the bedrock to eroding, the higher the rating. Slopes were rated as follows: 0-10% were rated as a 1, 10-15% 20% were rated as a 3, and slopes greater than 20% were rated as a 5. Bedrock lithology was rated using a similar system. A rating of 1 was assigned to formations having few documented landslides through a rating of 5 for those formations with extensive landslide development.

After these three layers were classified they were converted into raster data sets of 10 meter resolution. This provided for the ratings from each layer to be added together and given a total score. The range of possible scores is 3 through 14. A rating of 3 through 6 indicates low landslide susceptibility, 7 through 9 slight susceptibility, 10 through 12 moderate susceptibility, and 13 through 14 high susceptibility to landslides.

Landslide Susceptibility

- Low
- Slight
- Moderate
- High
- Urban Land, Severly Disturbed Soil, or Water

1:69,181

NORTHERN KENTUCKY UNIVERSITY

Environmental Resource Management Center
and
Department of Physics and Geology
Geology Program

Parameters for Landslide Susceptibility Map for Northern Kentucky

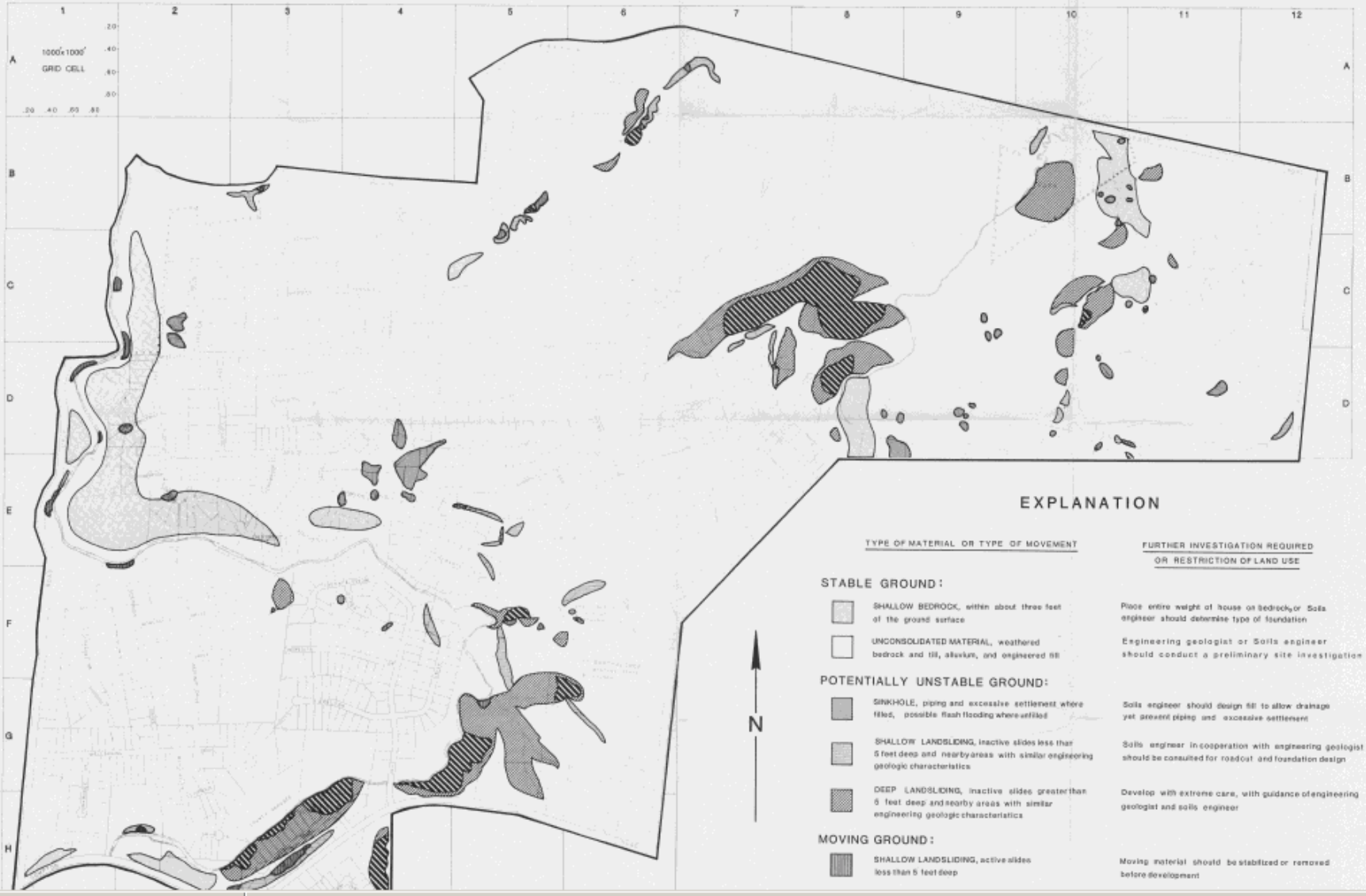
Variable	Ranking
Soil	1- 4
Slope 0-10%	1
Slope 10.01-20%	3
Slope > 20%	5
Bedrock	1-5

Key

Total Sum Value	Zone
3 – 6	Low
7 – 9	Slight
10 – 12	Moderate
13 – 14	High

in part of Springfield Township, Hamilton County, Ohio

PLATE 3



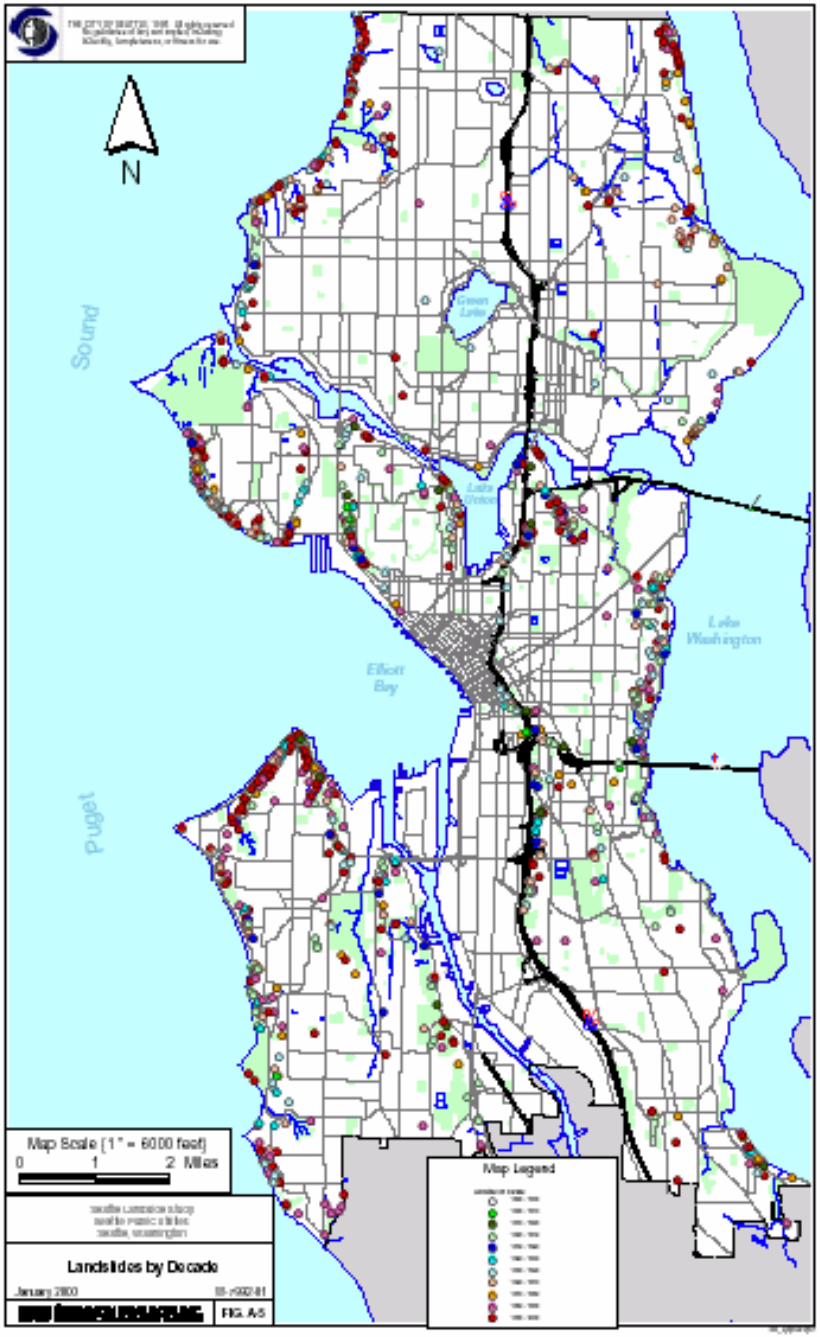
EXPLANATION

TYPE OF MATERIAL OR TYPE OF MOVEMENT	FURTHER INVESTIGATION REQUIRED OR RESTRICTION OF LAND USE
STABLE GROUND:	
SHALLOW BEDROCK, within about three feet of the ground surface	Place entire weight of house on bedrock, or Soils engineer should determine type of foundation
UNCONSOLIDATED MATERIAL, weathered bedrock and till, alluvium, and engineered fill	Engineering geologist or Soils engineer should conduct a preliminary site investigation
POTENTIALLY UNSTABLE GROUND:	
SINKHOLE, piping and excessive settlement where filled, possible flash flooding where unfilled	Soils engineer should design fill to allow drainage yet prevent piping and excessive settlement
SHALLOW LANDSLIDING, inactive slides less than 5 feet deep and nearby areas with similar engineering geologic characteristics	Soils engineer in cooperation with engineering geologist should be consulted for roadcut and foundation design
DEEP LANDSLIDING, inactive slides greater than 5 feet deep and nearby areas with similar engineering geologic characteristics	Develop with extreme care, with guidance of engineering geologist and soils engineer
MOVING GROUND:	
SHALLOW LANDSLIDING, active slides less than 5 feet deep	Moving material should be stabilized or removed before development

Landslide Inventory

Portions of the report require that Adobe Acrobat Reader be installed
Click the following image to install from CD.

Click to enter the Seattle Landslide Study


N
Sound
Lake Union
Lake Washington
Elliott Bay
Puget
Map Scale (1" = 6000 feet)
0 1 2 Miles
Map Legend
Landslides by Decade
January 2000
FIG. A-5

Seattle Landslide Study
Seattle Public Utilities
Seattle, Washington

Seattle Landslide Database

(appended 5/2003)

SHANNON & WILSON
W-7992-01

LANDSLIDE IDENTIFICATION								LANDSLIDE CHARACTERISTICS						STRATIGRAPHY (Geology)				TRIGGER MECHANISM(s)					ROADS and PUBLIC UTILITY IMPACT				DAMAGE & REPAIR		
Record Number	Location	Date	Failure Year	File Number	Consultant Report	Field Checked	Date Confidence	Slope Height	Landslide Type	Debris Flow	Size	Vegetation	Topography	Unit 1	Unit 2	Unit 3	Unit 4	Natural	Ground Water	Surface Water	Fill and/or Cut	Road Cut and/or Fill	Surface Drain	Pipe Leak	Trench Fill	Damage	Repair Type	Repair Effective	Record Number
1	10025 46TH AV S	1997/01/01	1997	96-97 Storm		True	True	75	HBP	Y	L	T	SS					Y											1
3	825 YESLER WY	1910/12/01	1910	I-1-f		True	True	20	SC	Y	S	S	MS	HF	HC	QC		Y	Y	Y	Y	F				2			3
4	825 YESLER WY	1911/02/01	1911	I-1-f		True	True	20	SC	Y	S	S	MS	HF	HC	QC		Y	Y	Y	Y	F				2			4
5	825 YESLER WY	1912/01/01	1912	I-1-f		True	False	20	SC	Y	S	S	MS	HF	HC	QC		Y	Y	Y	Y	F				2			5
6	825 YESLER WY	1968/02/01	1968	I-1-f		True	True	20	SC	Y	S	S	MS	HF	HC	QC		Y	Y	Y	Y	F				2			6
7	1526 11TH AV S	1990/12/31	1990	S&W		True	True	70	SC	N	S	B	SS	HC	QS	QC		Y	Y	Y	N					2			7
8	1200 S LANDER ST	1934/01/01	1934	I-15-a		True	False	100	BO	Y	S	T	SS	HC	QT	QC		Y	Y	Y	Y	F		Y		0			8
9	1200 S LANDER ST	1938/01/01	1938	I-15-a		True	False	100	BO	Y	S	T	SS	HC	QT	QC		Y	Y	Y	Y	F		Y		0			9

Preliminary Method for Anticipating the Occurrence of Precipitation-Induced Landslides in Seattle, Washington

By **Alan F. Chleborad**

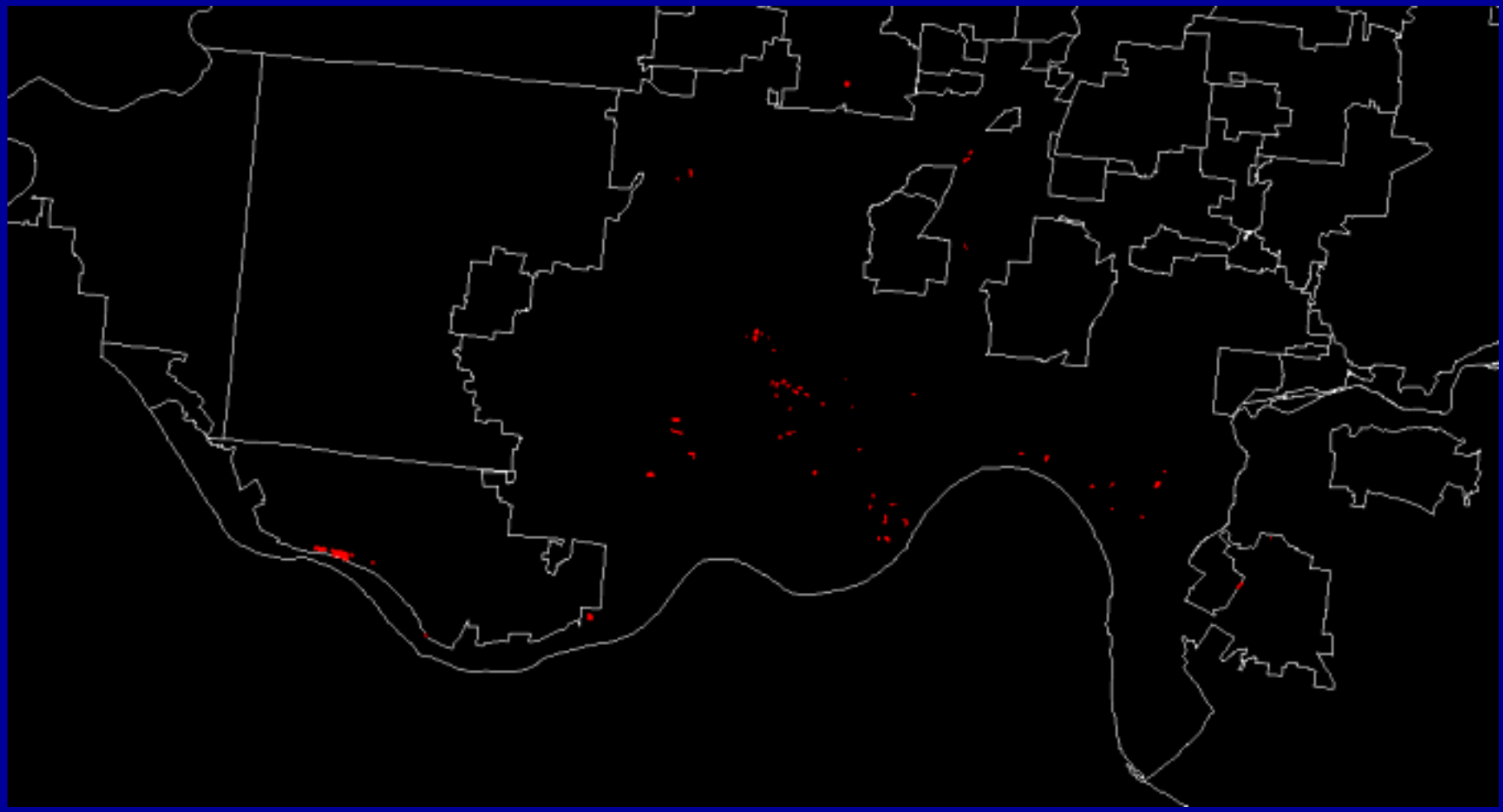
U.S. Geological Survey Open-File Report 00-0469

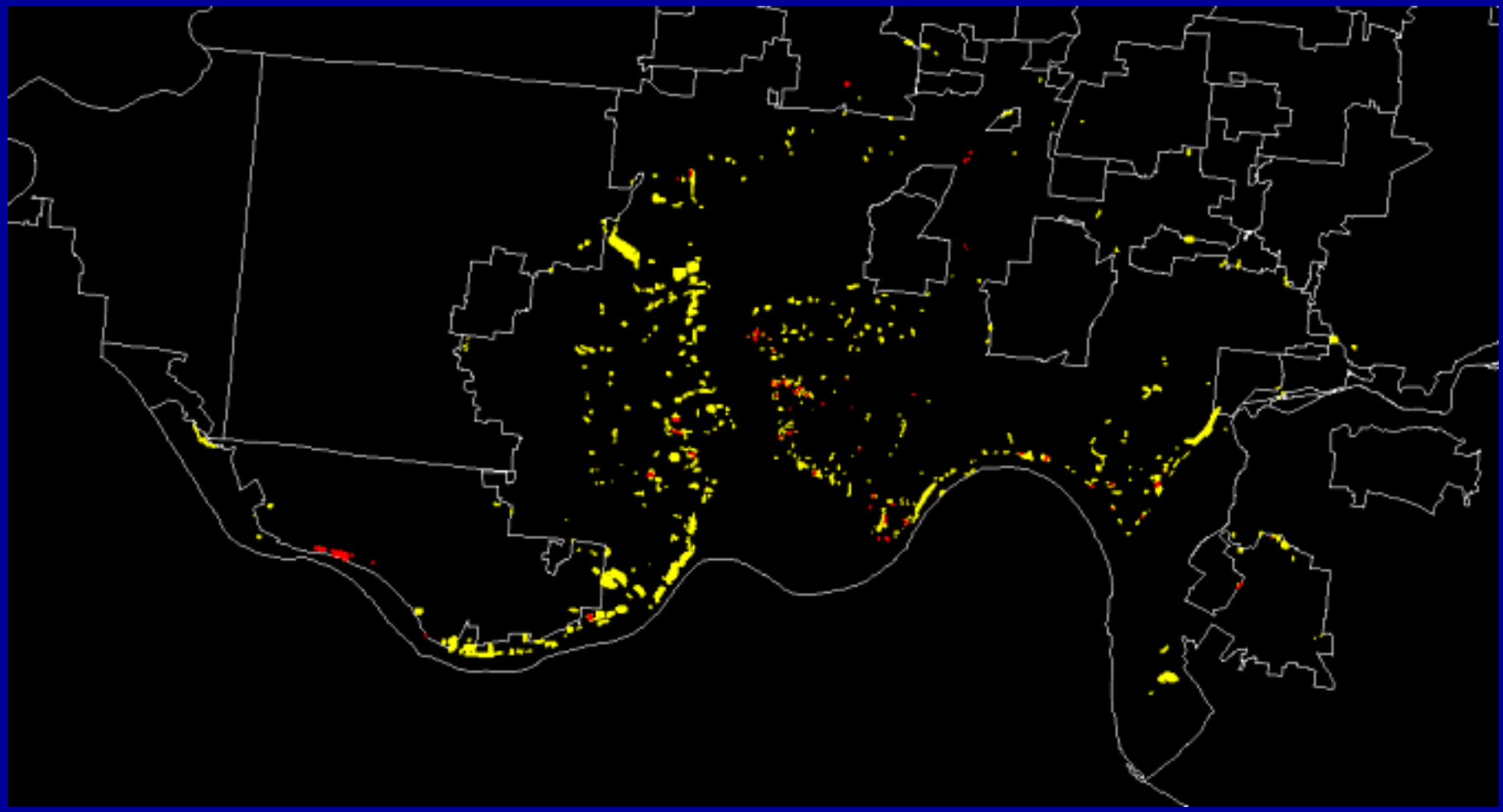
Version 1.0

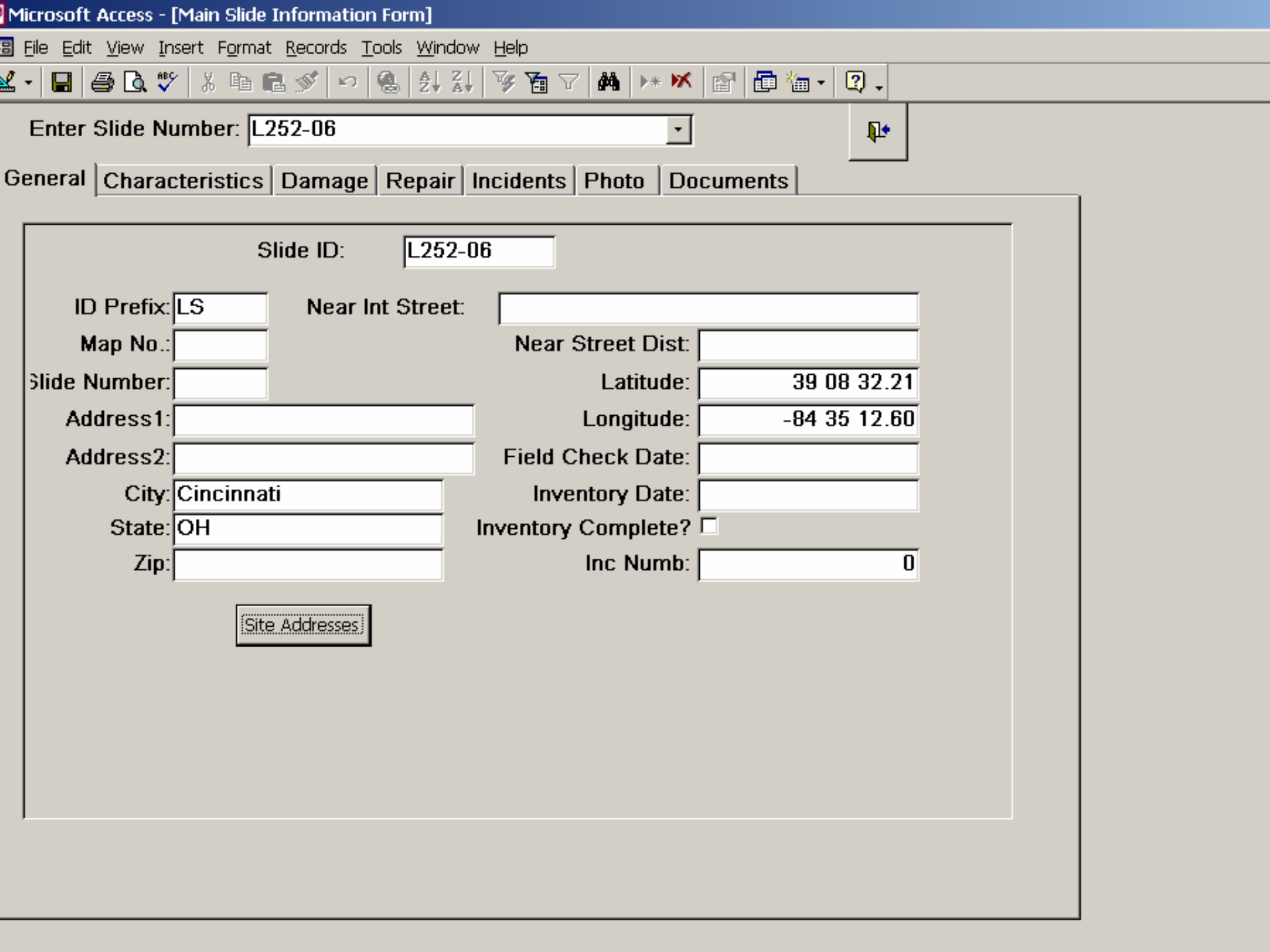
Preliminary map showing landslide densities, mean recurrence intervals, and exceedance probabilities as determined from historic records, Seattle, Washington

by J.A. Coe, J.A. Michael, R.A. Crovelli, and W.Z. Savage

Open-File Report 00-303, on-line edition 2000



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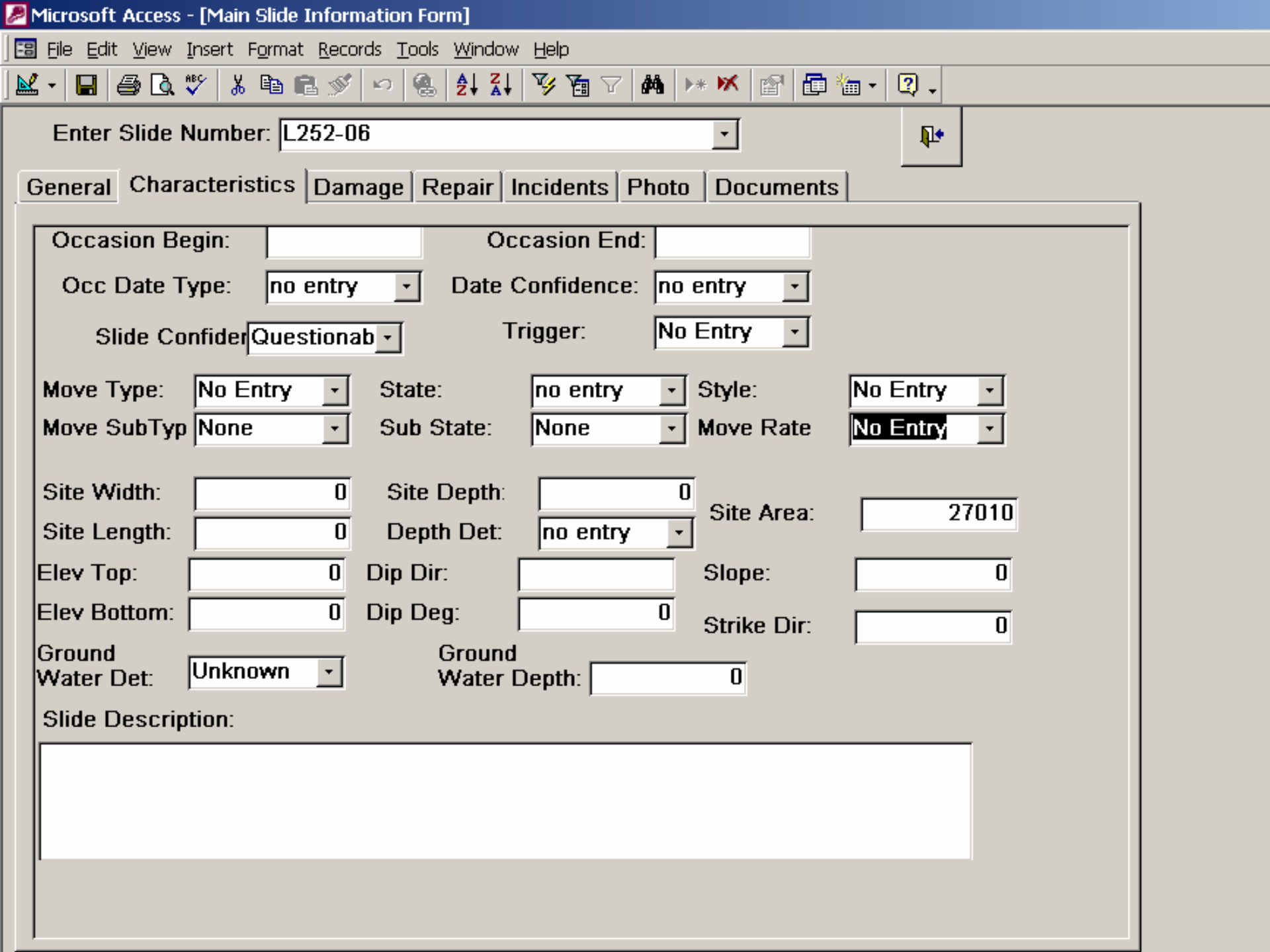
General Characteristics Damage Repair Incidents Photo Documents
Slide ID: L252-06
ID Prefix: LS
Near Int Street:
Map No.:
Near Street Dist:
Slide Number:
Latitude: 39 08 32.21
Address1:
Longitude: -84 35 12.60
Address2:
Field Check Date:
City: Cincinnati
Inventory Date:
State: OH
Inventory Complete?
Zip:
Inc Numb: 0
Site Addresses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General Characteristics Damage Repair Incidents Photo Documents
Occasion Begin:
Occasion End:
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Date Confidence: no entry
Slide Confider Questionab
Trigger: No Entry
Move Type: No Entry
State: no entry
Style: No Entry
Move SubTyp None
Sub State: None
Move Rate No Entry
Site Width: 0
Site Depth: 0
Site Area: 27010
Site Length: 0
Depth Det: no entry
Elev Top: 0
Dip Dir:
Slope: 0
Elev Bottom: 0
Dip Deg: 0
Strike Dir: 0
Ground Water Det: Unknown
Ground Water Depth: 0
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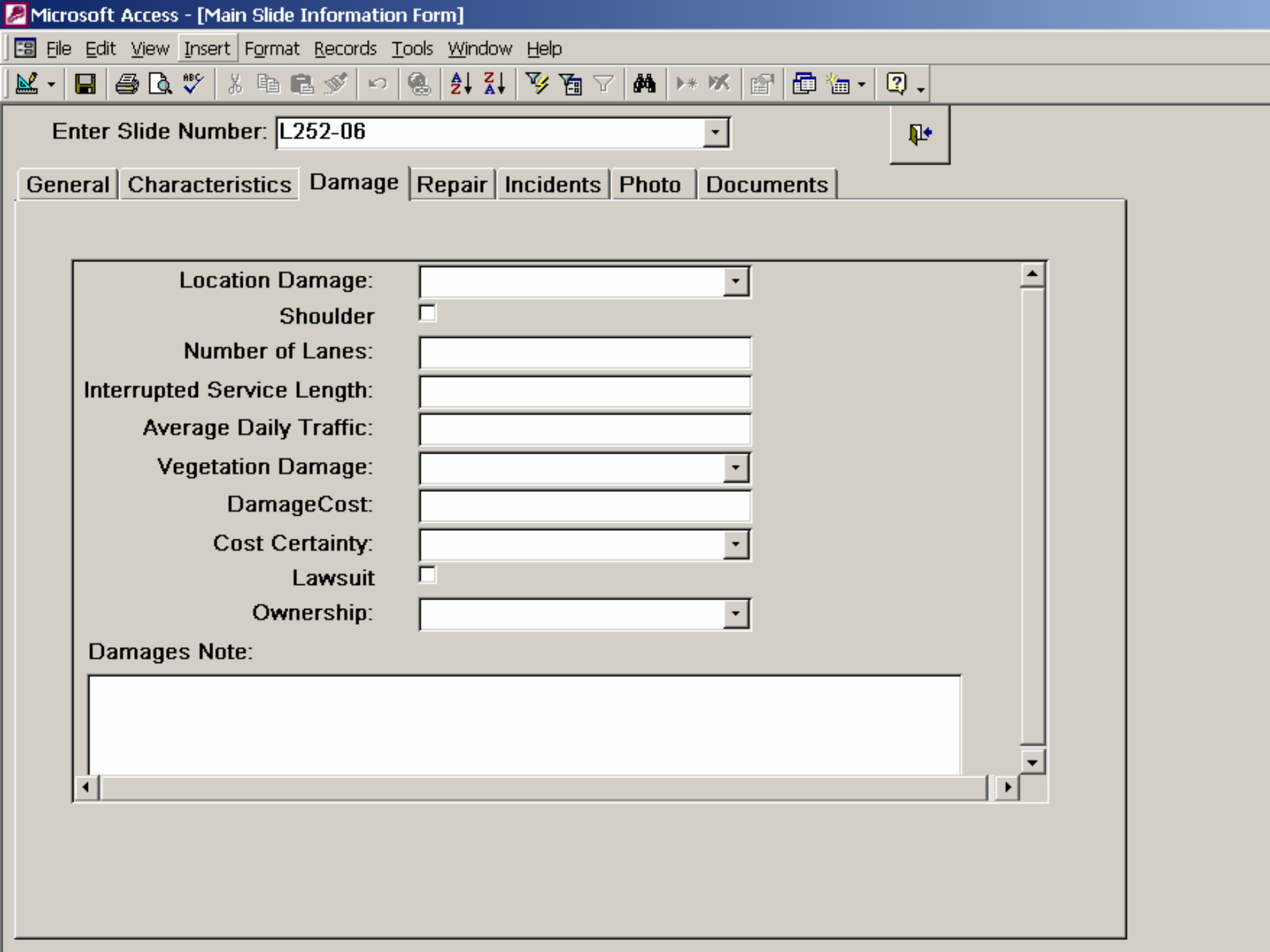
Microsoft Access - [Main Slide Information Form]
File Edit View Insert Format Records Tools Window Help
Enter Slide Number: L252-06
General Characteristics Damage Repair Incidents Photo Documents
Location Damage:
Shoulder
Number of Lanes:
Interrupted Service Length:
Average Daily Traffic:
Vegetation Damage:
DamageCost:
Cost Certainty:
Lawsuit
Ownership:
Damages Note:

Microsoft Access - [Main Slide Information Form]

File Edit View Insert Format Records Tools Window Help

Enter Slide Number: L252-06

General | Characteristics | Damage | Repair | Incidents | Photo | Documents

Repair Status: Repair Length:

Construction Start Date: Construction End Date:

Geotechnical Investigator:

Test Borings:

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Piezometer Note:

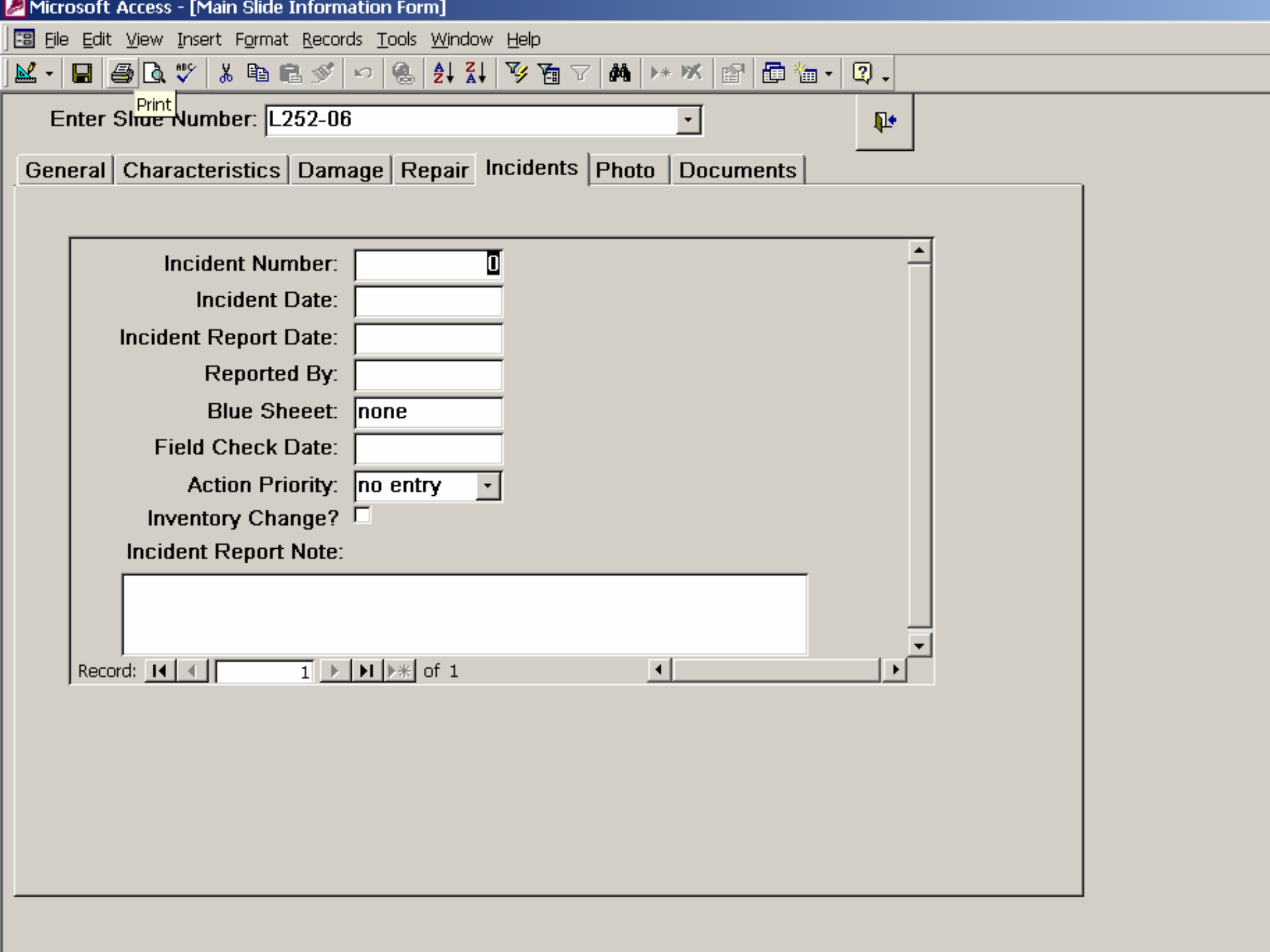
Repair Cost:

Repair CostCertainty:

Funding Source:

Repair Note:

Record: 1 of 1


Microsoft Access - [Main Slide Information Form]
File Edit View Insert Format Records Tools Window Help
Print
Enter Slide Number: L252-06
General Characteristics Damage Repair Incidents Photo Documents
Incident Number:
Incident Date:
Incident Report Date:
Reported By:
Blue Sheeet: none
Field Check Date:
Action Priority: no entry
Inventory Change?
Incident Report Note:
Record: 1 of 1

Scale 1: 794

al View

thophoto

ndslide.shp

unicipalities & Townships

contours.shp
0
1 - 500
501 - 650
651 - 750
751 - 900

ty Of Cincinnati Boundary

outes_state.shp

outes_municipal.shp

uadgeo_line.shp

outes_local.shp

uadgeo_poly.shp
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LS
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U1
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esolution Level: 9

Scale 1: 794

Tool That Writes Attributes of Selected Features of Active Themes to a File

thophoto

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unicipalities & Townships

contours.shp
0
1 - 500
501 - 650
651 - 750
751 - 900

ty Of Cincinnati Boundary

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outes_municipal.shp

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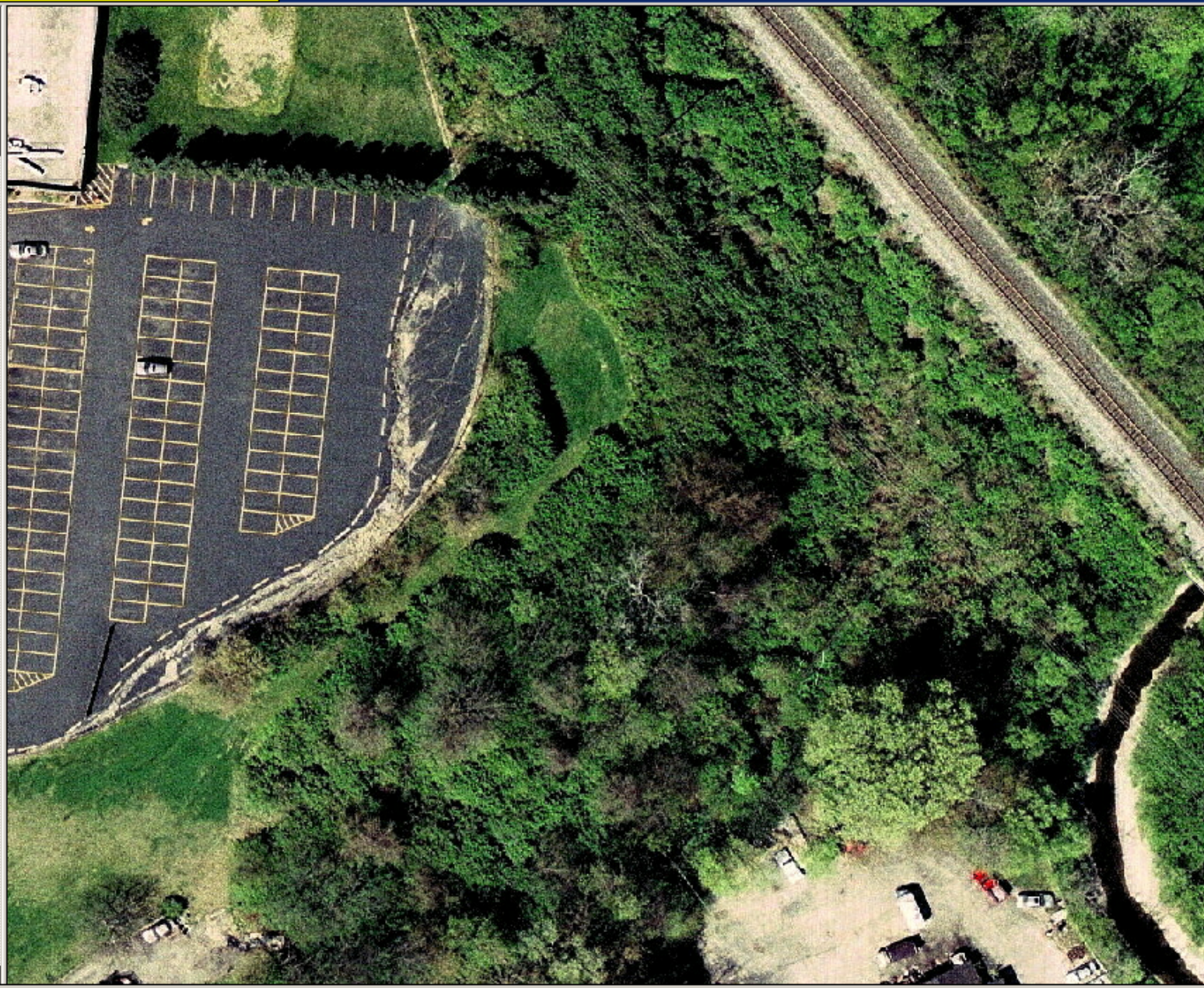
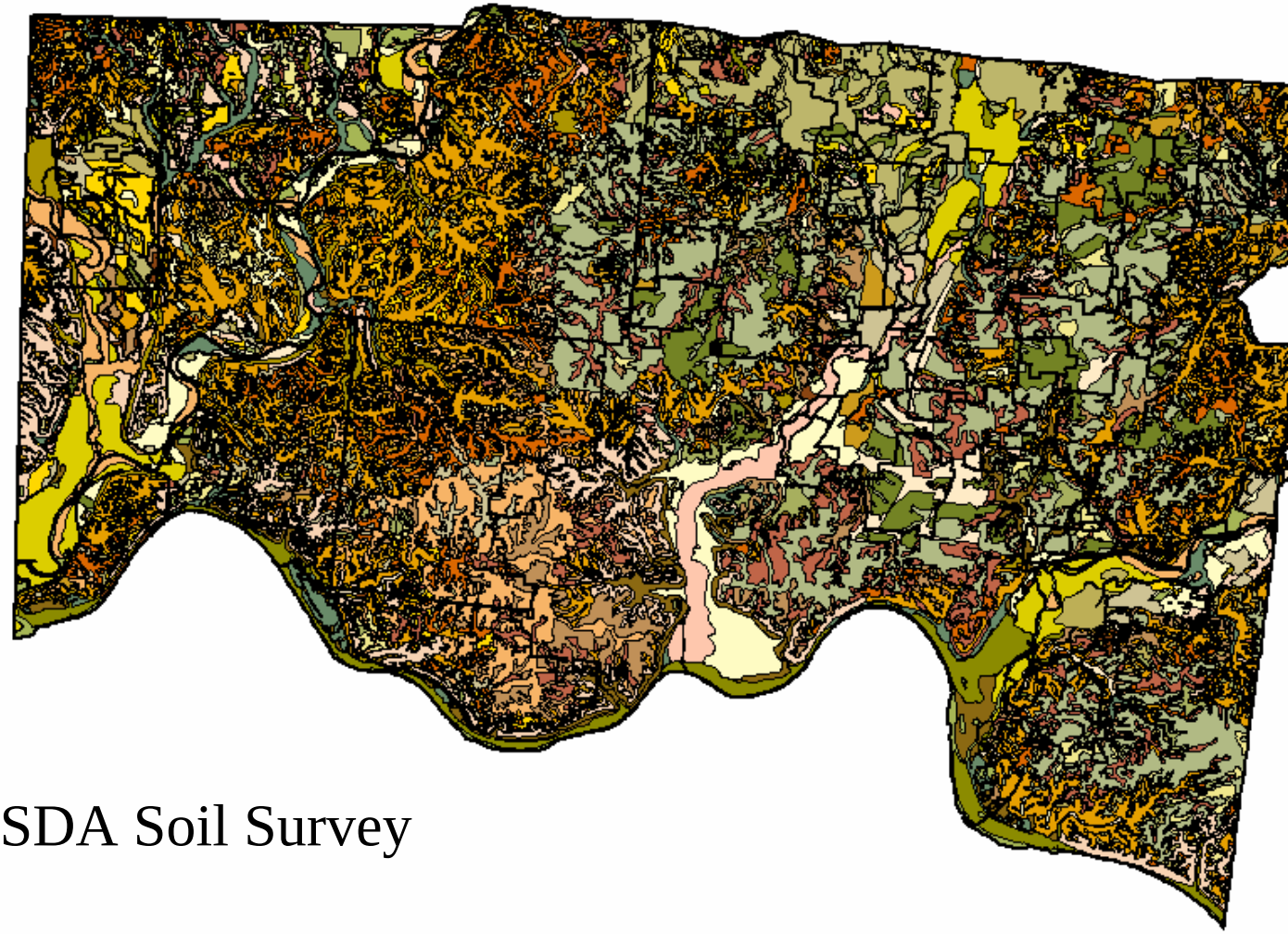


Geologic Data (parameter maps)

Scale 1: 249,340

Local View

- Soils
  - ArA
  - ArB2
  - ArC2
  - AsB
  - AsC
  - AvA
  - AwA
  - BoD
  - BoE
  - BoF
  - CcC2
  - CdD
  - CdE
  - CdF
  - CnB2
  - CnC2
  - DaB
  - Dam
  - EcB2
  - EcC2
  - EcD
  - EcE
  - EdF
  - EeB
  - EeC
  - EeD
  - EpA
  - EpB2
  - EpC2
  - ErA
  - ErB
  - FdA
  - FeA
  - FoA
  - FoB2
  - FpA
  - Gn
  - Go
  - HeF
  - HoA
  - Hu
  - Ju
  - Lg
  - MaB
  - MaC2



USDA Soil Survey

Scale 1: 249,340

Local View

1278 - 1702
1703 - 2128

Slopemon.shp

Unstable.shp

Regional Cities And Townships

Slope
- 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30

Walls

Streams

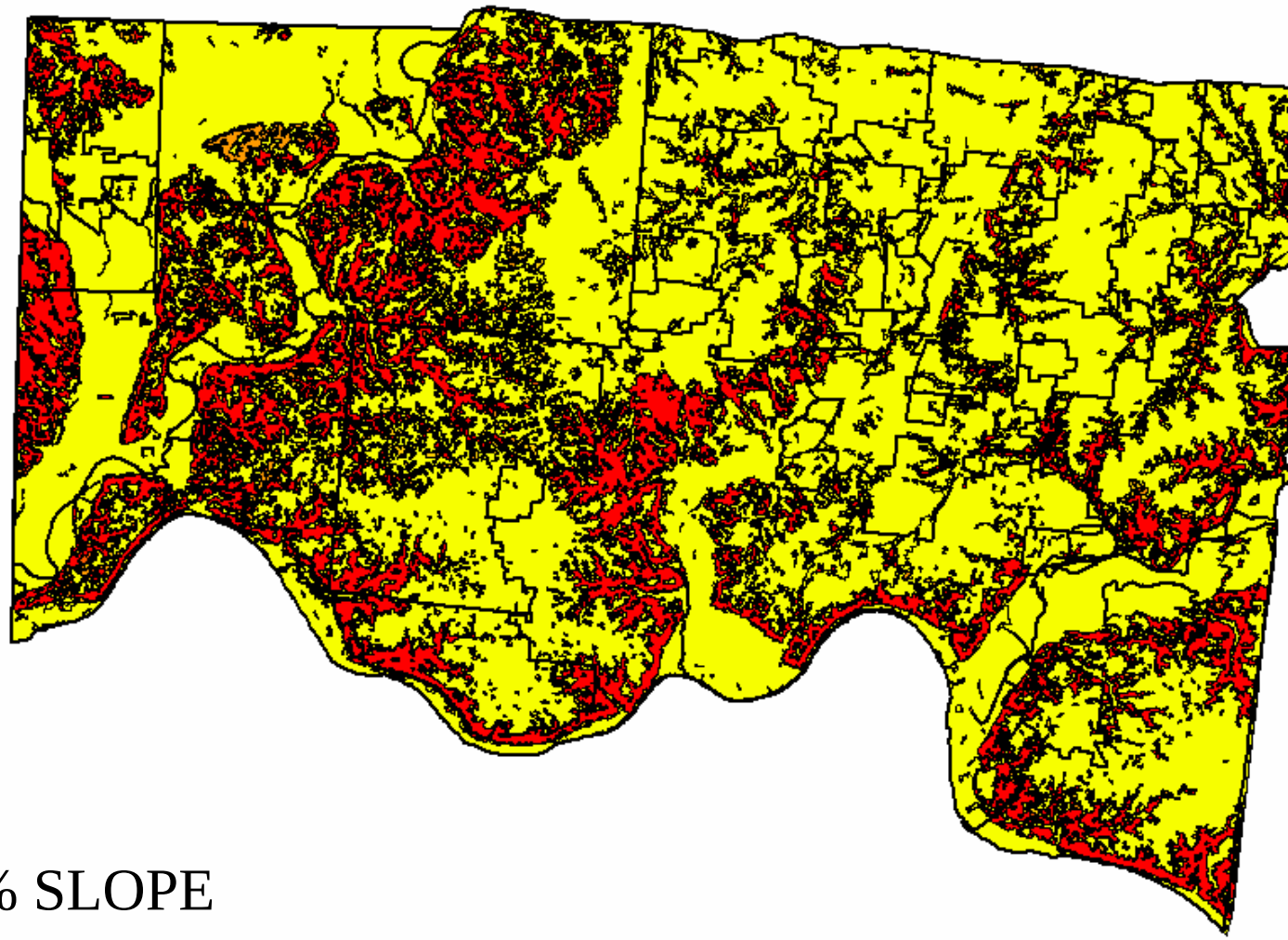
Rivers & Streams

Drainage

Streets Changes

Streets
- Local Streets (TBV)
- Interstate Highway
- US & State Rts
- Arterial Roads
- Collector Roads
- Local Streets
- Highway Ramps

200 Scale Grid



% SLOPE

Scale 1: 287,102

Local View

UrB
Ux
W
Wa
WbA
WeA
WhA
XfA
XfB2
int

Landslide.shp
Outside
Low
Moderate
Moderately High
High

Geology_poly.shp
ARNHEIM FORMATION
BELLEVUE MEMBER
FAIRVIEW FORMATION
GRANT LAKE FORMATION
KOPE FORMATION
MIAMITOWN SHALE-FAIRV
POINT PLEASANT FORMA
WAYNESVILLE FORMATIO
WAYNESVILLE FORMATIO

REGIONAL COUNTY BOUNDARI

PARCEL POLYGONS

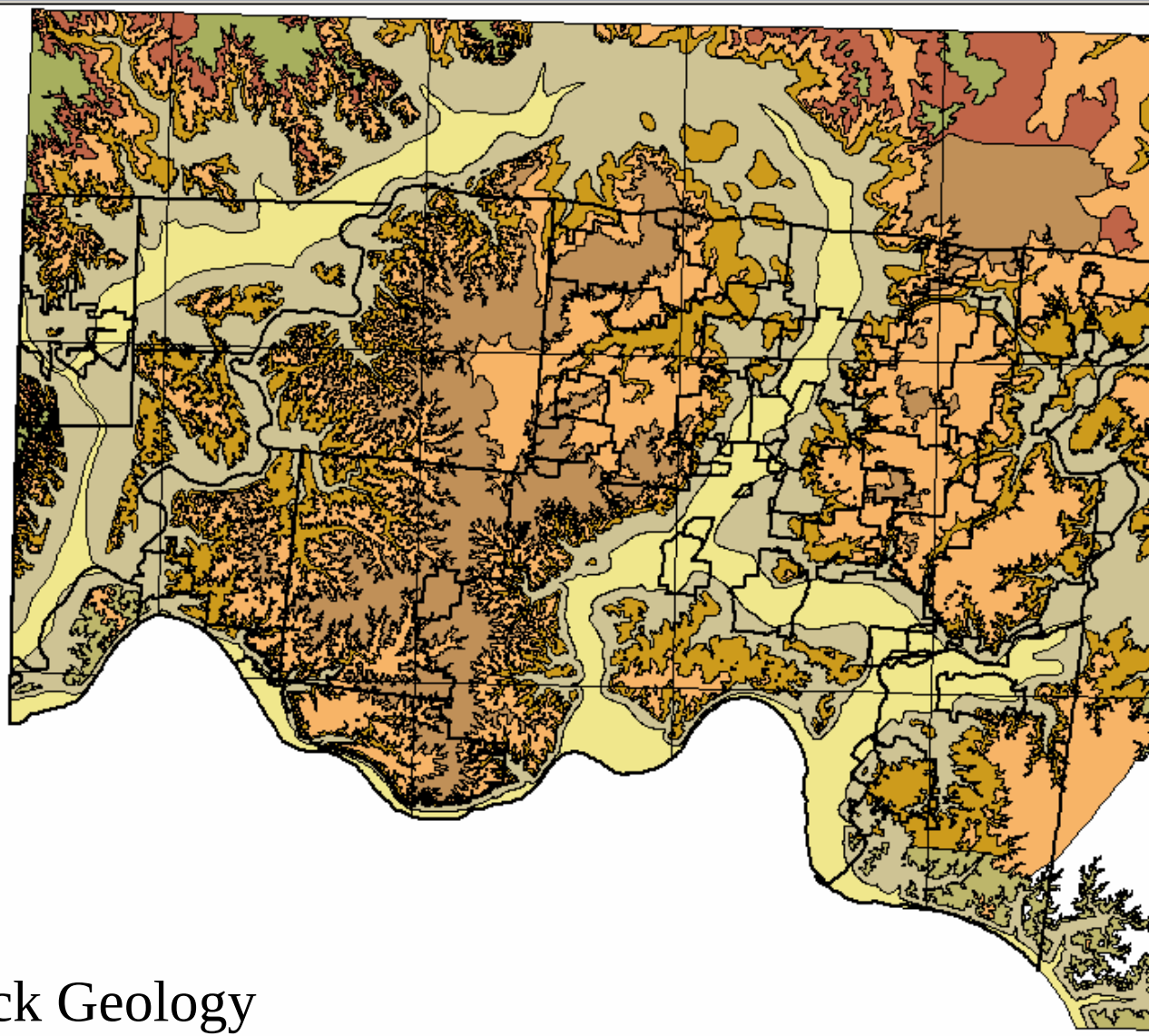
PARCEL ATTRIBUTES

CONDOS

CONDO ATTRIBUTES

ADDRESS

INTERSECTIONS



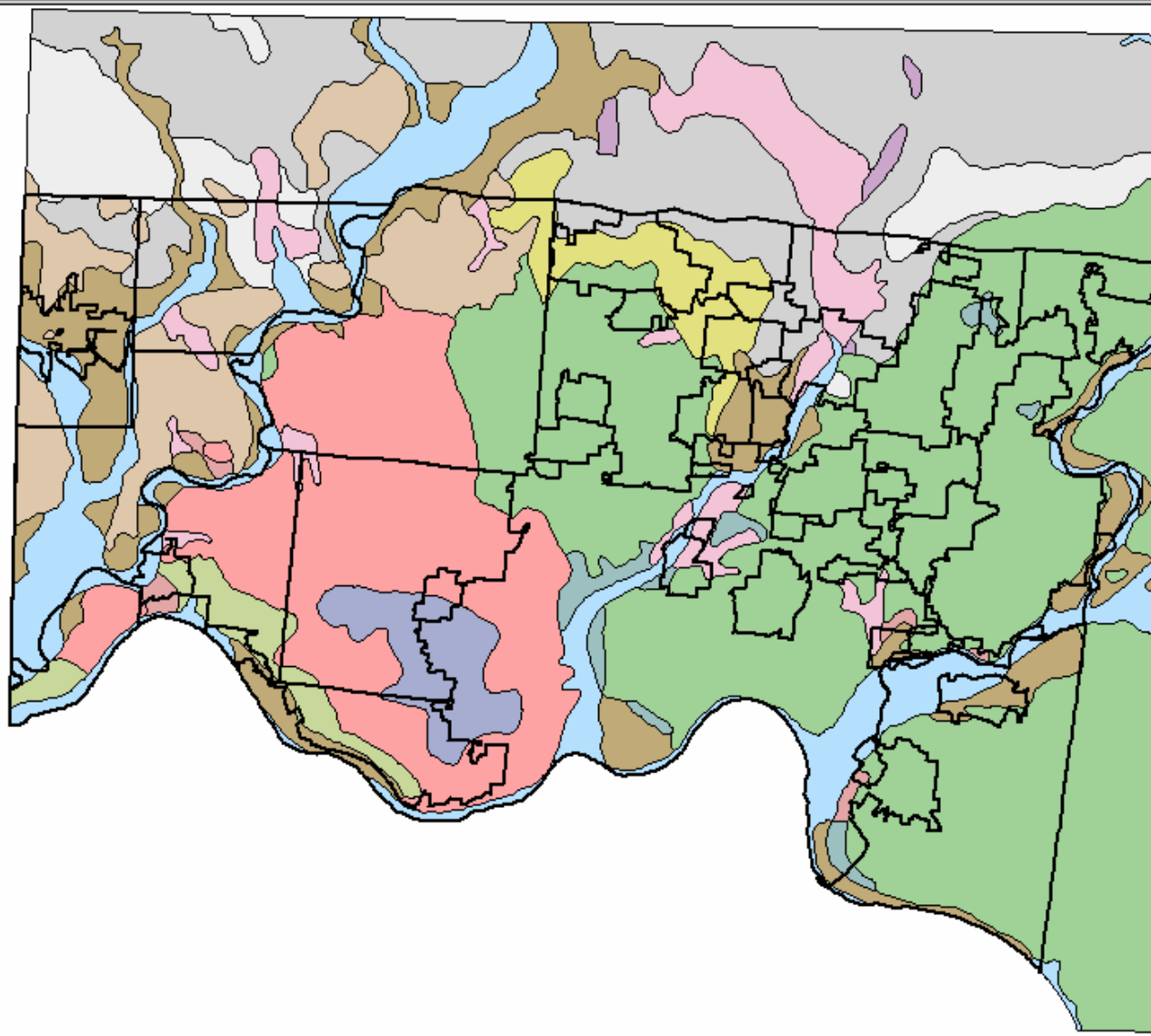
Bedrock Geology

ODNR Geol. Survey

Scale 1: 287,102

Local View

- 0
- 1 - 500
- 501 - 650
- 651 - 750
- 751 - 900
- City Of Cincinnati Boundary
- Routes_state.shp
- Routes_municipal.shp
- Quadgeo_line.shp
- Routes_local.shp
- Quadgeo_poly.shp
  - G1
  - Ic
  - Id
  - Ig
  - Io
  - K
  - Kd
  - Kg
  - Ks
  - LL
  - LS
  - M1
  - OU
  - U1
  - a
- Quad24k.shp
- Probablekarst.shp
- Knownkarst_pts.shp
- Knownkarst_poly.shp
- Geology_poly_arcs.shp



Origin: (1,285,231.73, 370,439.62) ft Extent: (201,784.65, 121,070.79) ft Area: 24,430,226,422.62 sq ft

Evaluation

Evaluation of Existing Landslide Susceptibility Maps

1980 Landslide Susceptibility Map
Of Cincinnati

Anderson Township Hillside
Development Districts

vs.

Landslides in original study

Additional Landslides
omitted from study
after completion of study

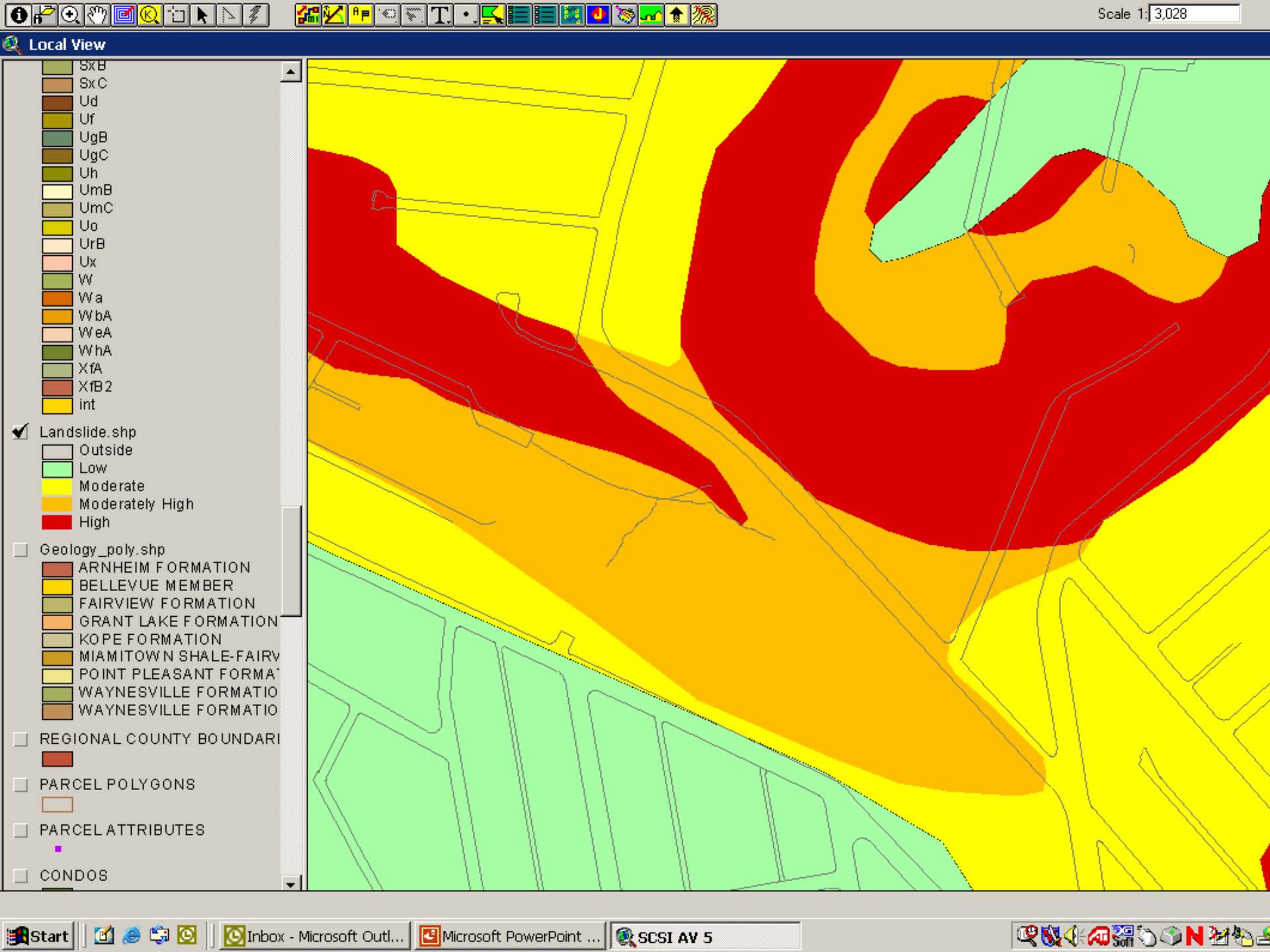
Theses Studies

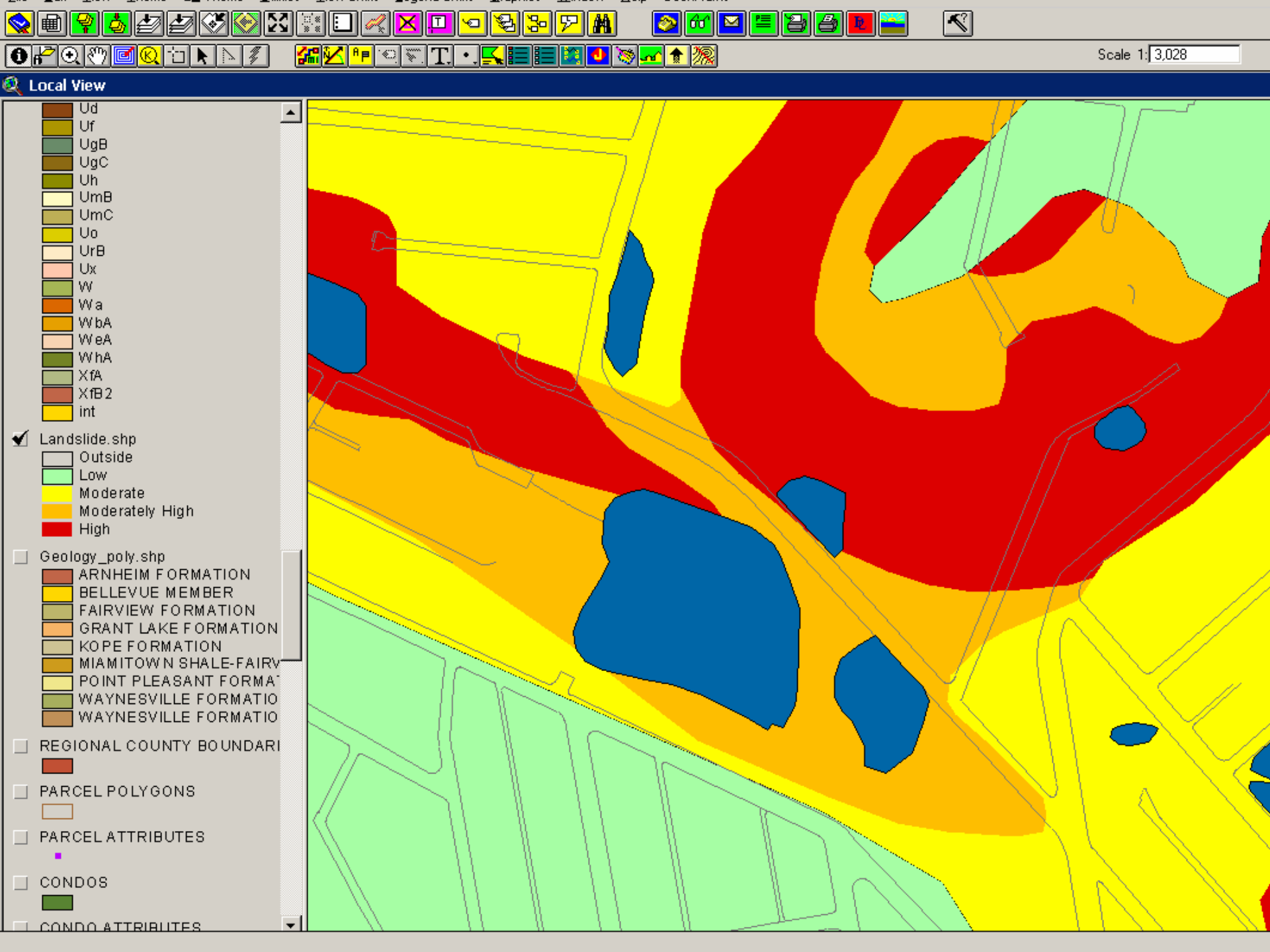
Ham. Co. (CAGIS) vs. All inventoried landslides

Generation of New Landslide Susceptibility Maps for Cincinnati and Anderson Township

- Reproduce maps using original parameters
- Reanalyze with new data using bivariate method
- Reanalyze with new data using multivariate method
- Compare results against one another & Theses Studies
- Extend each analysis into Hamilton County compare results with County Landslide Inventory Data
- Compare parameter weights of analyses with Northern Kentucky's, possibly extend each analysis into Northern Kentucky

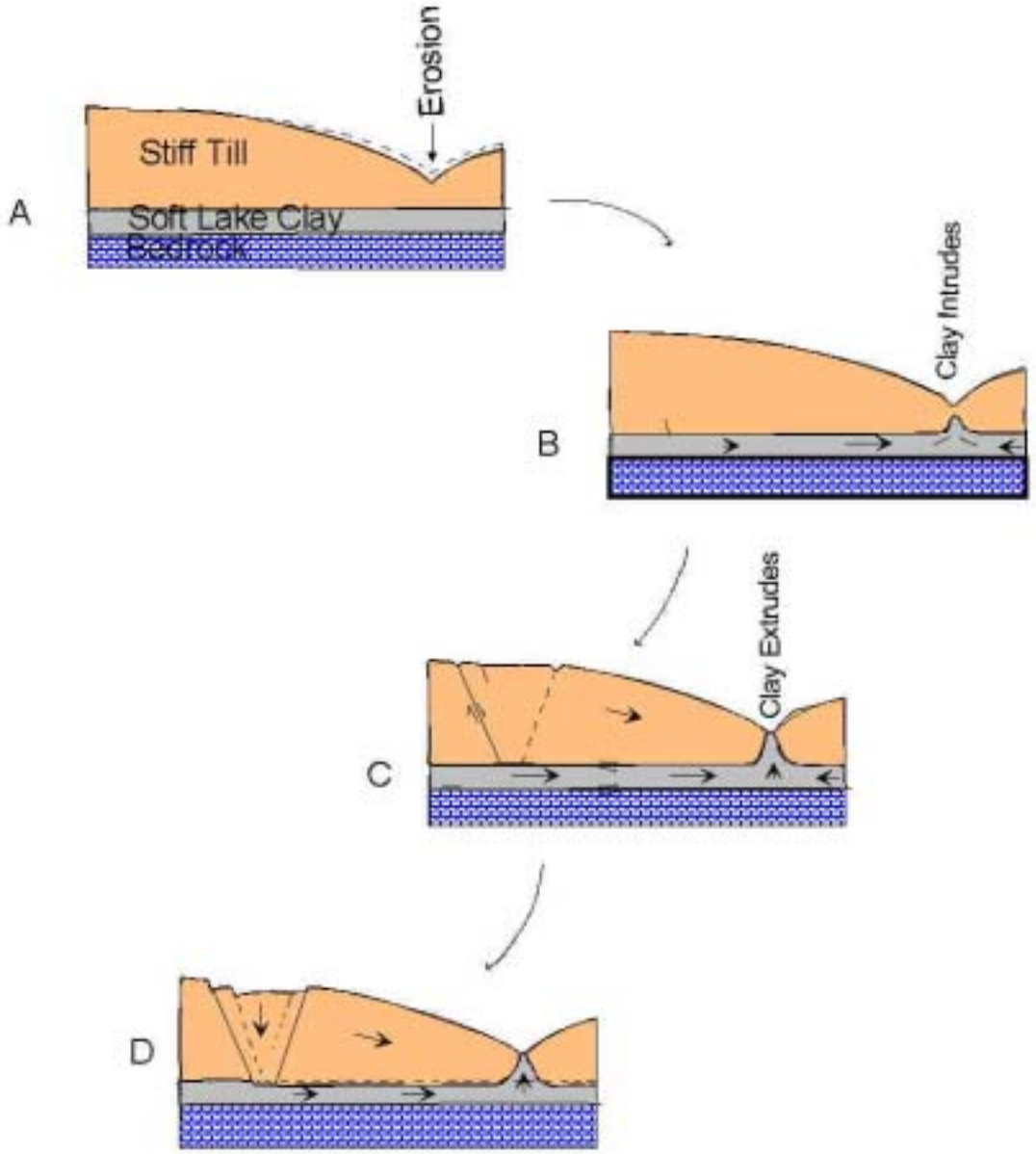
Anticipated Results

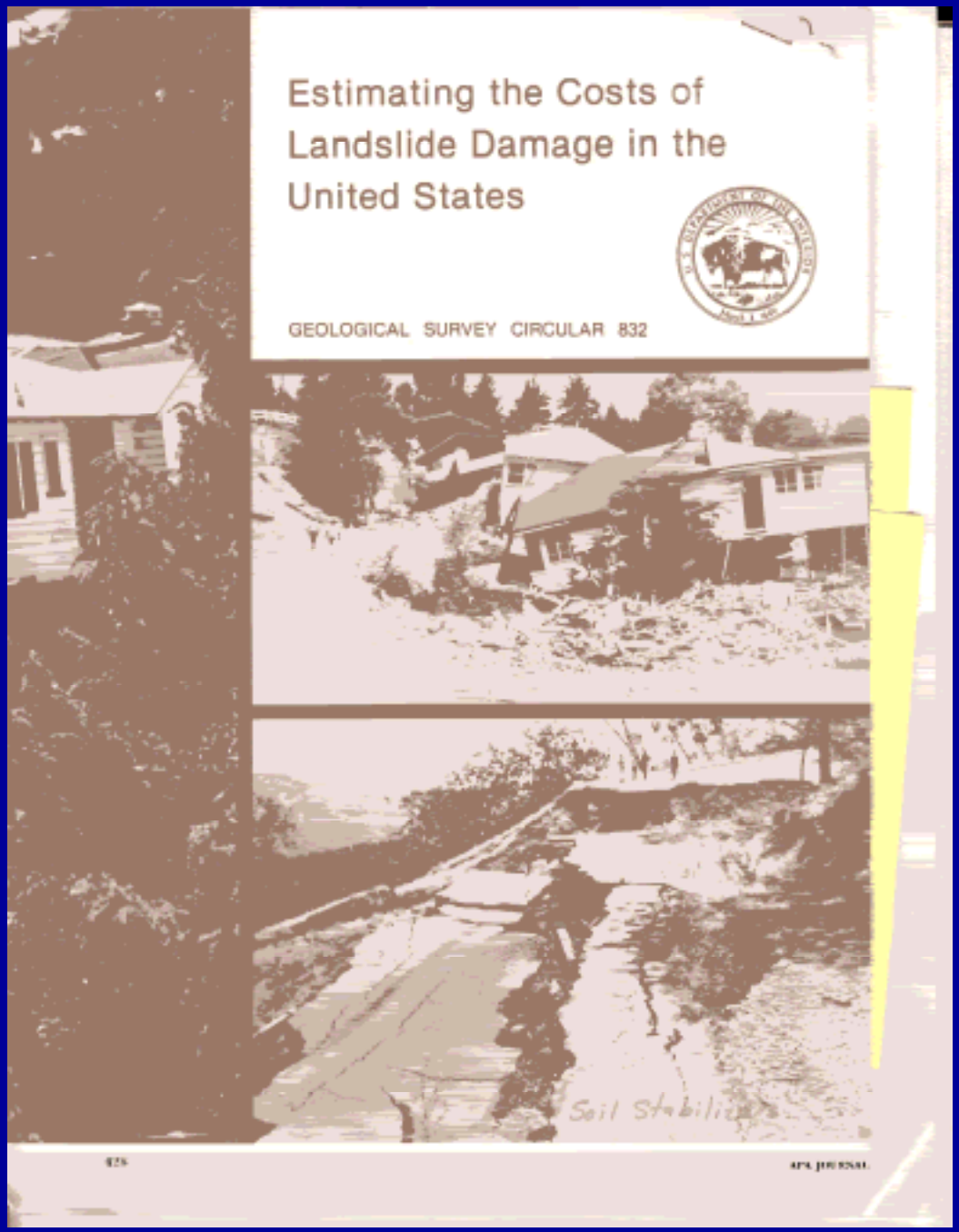

Scale 1: 3,028
Local View
SxB
SxC
Ud
Uf
UgB
UgC
Uh
UmB
UmC
Uo
UrB
Ux
W
Wa
WbA
WeA
WhA
XfA
XfB2
int
Landslide.shp
Outside
Low
Moderate
Moderately High
High
Geology_poly.shp
ARNHEIM FORMATION
BELLEVUE MEMBER
FAIRVIEW FORMATION
GRANT LAKE FORMATION
KOPE FORMATION
MIAMITOWN SHALE-FAIRV
POINT PLEASANT FORMA
WAYNESVILLE FORMATIO
WAYNESVILLE FORMATIO
REGIONAL COUNTY BOUNDARI
PARCEL POLYGONS
PARCEL ATTRIBUTES
CONDOS
Start
Inbox - Microsoft Outl...
Microsoft PowerPoint ...
SCSI AV 5


Scale 1: 3,028
Local View
Ud
Uf
UgB
UgC
Uh
UmB
UmC
Uo
UrB
Ux
W
Wa
WbA
WeA
WhA
XfA
XfB2
int
Landslide.shp
Outside
Low
Moderate
Moderately High
High
Geology_poly.shp
ARNHEIM FORMATION
BELLEVUE MEMBER
FAIRVIEW FORMATION
GRANT LAKE FORMATION
KOPE FORMATION
MIAMITOWN SHALE-FAIRV
POINT PLEASANT FORMA
WAYNESVILLE FORMATIO
WAYNESVILLE FORMATIO
REGIONAL COUNTY BOUNDARI
PARCEL POLYGONS
PARCEL ATTRIBUTES
CONDOS
CONDO ATTRIBUTES

310E
M

Extrusion Mechanism





Cost per Capita

$5.80 Hamilton Co., Ohio

$2.50 Allegheny Co., Penn.

$1.80 9-Co., SF Bay, Calf.

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

National Landslide Hazards Mitigation Strategy

A Framework For Loss Reduction

U.S. Geological Survey
Open-File Report 00-450
2000

1. **Research:** Developing a predictive understanding of landslide processes and triggering mechanisms.
2. **Hazard Mapping and Assessments:** Delineating susceptible areas and different types of landslide hazards at a scale useful for planning and decision-making
3. **Real-Time Monitoring**: Monitoring active landslides that pose substantial risk.
4. **Loss Assessment**: Compiling and evaluating information on the economic impacts of landslide hazards.
5. **Information Collection, Interpretation, and Dissemination**: Establishing an effective system for information transfer.
6. **Guidelines and Training**: Developing guidelines and training for scientists, engineers, and decision-makers.
7. **Public Awareness and Education**: Developing information and education for the user community
8. **Implementation of Loss Reduction Measures**: Encouraging mitigation action.
9. **Emergency Preparedness, Response, and Recovery**: Building resilient communities.

Earthflow in Cincinnati, Ohio. Material being removed by highway crew.

Cincinnati, Ohio—a Leader in Landslide Loss Reduction Measures

Landslides are a significant problem in several areas of Ohio and Cincinnati has one of the highest per-capita costs due to landslide damage of any city in the United States. Landslides have been known to occur in the Cincinnati area in southwestern Ohio and adjoining States of Kentucky and Indiana since before the 1850's, but the damage caused by landslides became increasingly expensive as urban development encroached more and more on the area's hillsides. The City of Cincinnati spent an average of about $550,000 per year on emergency street repairs for damage due to landslides between 1983 and 1987.

In 1974 the Cincinnati City Council passed an excavation and fill ordinance to help reduce landslide damage in areas of new construction. In 1980 Cincinnati created a geotechnical office within its Department of PublicWorks. The office, which is staffed by a geotechnical engineer, and engineering geologist, and two technicians, carries out a mitigation program. Since 1980, members of the geotechnical staff have worked in several ways to reduce landslide damage in the city; their work includes engineering-geologic mapping of selected parts of the city, inspection of retaining walls that impact public right-of-way, review of proposed construction in hillside areas, inspecting and arranging for repair of landslide areas that affect city property, and compiling geologic and geotechnical data on landslide areas within the city. In 1990, Hamilton County also adopted an excavation and fill ordinance to help reduce the damage due to landslides in areas of new construction.

From Ohio Department of Natural Resources "Geofacts," no. 8, by Michael C. Hansen, September 1993 and USGS Bulletin 2059-A "Overview of Landslide Problems, Research, and Mitigation, Cincinnati, Ohio, Area" by Rex L. Baum and Arvid M. Johnson, 1996.

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'96 6 7

The Post

Newscien

Friday, April 13, 1984

Cincinnati's sliding

By Randy Ludlow
Post Staff Reporter

The prehistoric forces that formed the lay of the land were kind to Greater Cincinnati.

Unlike most Midwestern regions, which are flat and dull, Cincinnati is blessed with hillsides that provide views of the valleys below and inject greenery into the urban landscape.

Those same slopes, however, make Cincinnati one of the nation's worst areas for landslides, experts say. Slowly and surely, portions of Greater Cincinnati are sliding away.

Consider:

• Landslide damage and related costs averaged $12 annually for each Hamilton County resident, the highest per capita figure in the nation, in 1980. Experts doubt that ranking has changed.

• County landslide losses amounted to more than $30 million from 1968 to 1980, not including the well-publicized $26 million project to stabilize the southwestern flank of Mt. Adams, which began to slide when I-471 cut across its base.

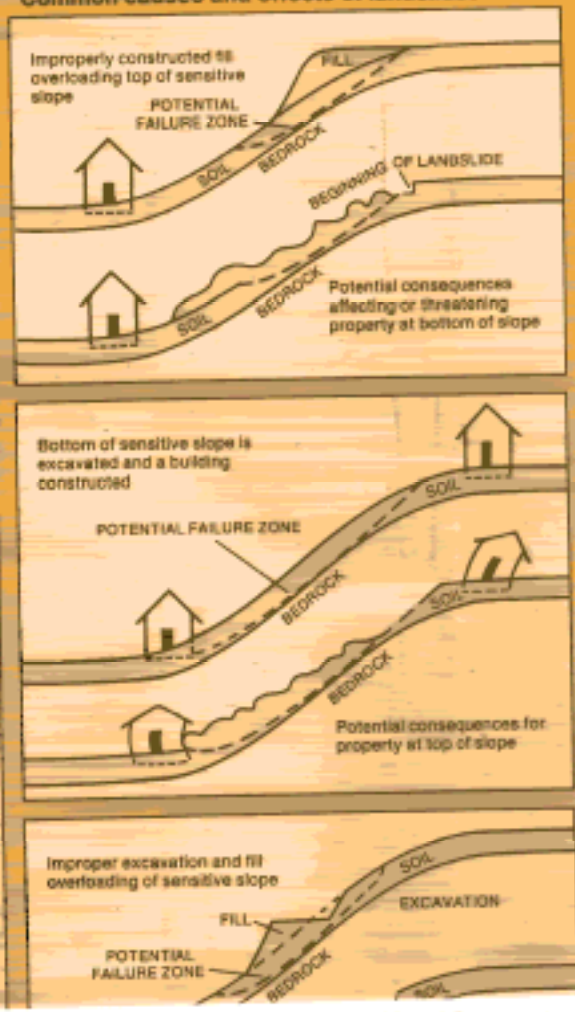
• Two to three dozen buildings are condemned annually in Hamilton County due to landslide problems. Thousands of others are endangered or damaged by earth movement that shifts and cracks building foundations and frames, driveways, sidewalks, water and sewer lines and swimming pools.

Greater Cincinnati has had several notorious landslides. Heavy spring rains triggered landslides in 1973 that caused $5.5 million in damage, particularly along Hillside Avenue in Delhi Township. One landslide destroyed about 40 Cincinnati houses between 1927 and 1930.

Areas plagued with landslide problems are Columbia Parkway, McMillian Street, West Fork Road in Mt. Airy Forest, Anderson Township and parts of Price Hill and Mt. Auburn and other neighborhoods.

Some landslides occur naturally, but man's construction of everything

Common causes and effects of landslides



Consider:

• Landslide damage and related costs averaged $12 annually for each Hamilton County resident, the highest per capita figure in the nation, in 1980. Experts doubt that ranking has changed.

• County landslide losses amount-

Chung (2003) Validation of Spatial Prediction Models for Landslide Hazard Mapping

R= prediction class of size r

T= study area size t

A=target area (area affected by future landslides) of size z

q=portion of future landslide area z that has occurred within that class

Probability that pixel within the class = q/r
will be affected by a future landslide is

Probability of any pixel in the study area = z/t
To be affected by a future landslide

Predictive power of a prediction class = qt/rz
(ratio of effectiveness)

Near 1 randomly selected
> 3 or < 0.2 significant
>6 or < 0.1 significantly effective

Prediction Classes

Equal-interval classes – range of all pixels values divided into a number of equal intervals, class assigned to each interval number of pixels in each class are different.

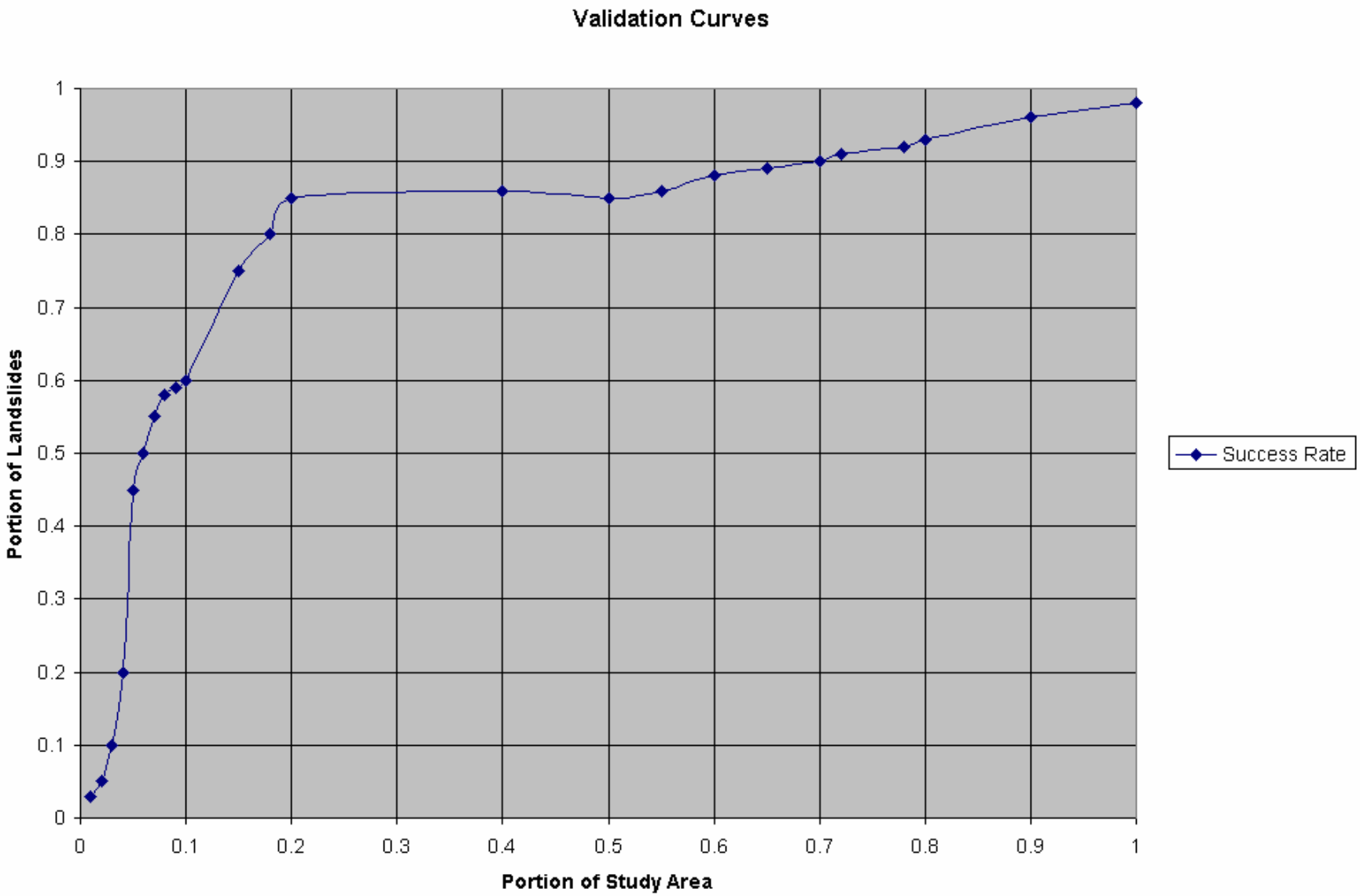
Ranking equal number – each class determined by equal number of pixels ranked in order, each class assigned an equal number of pixels (implies that the ranking of the predicted pixel values in the image is more significant that the actual numerical predicted value.

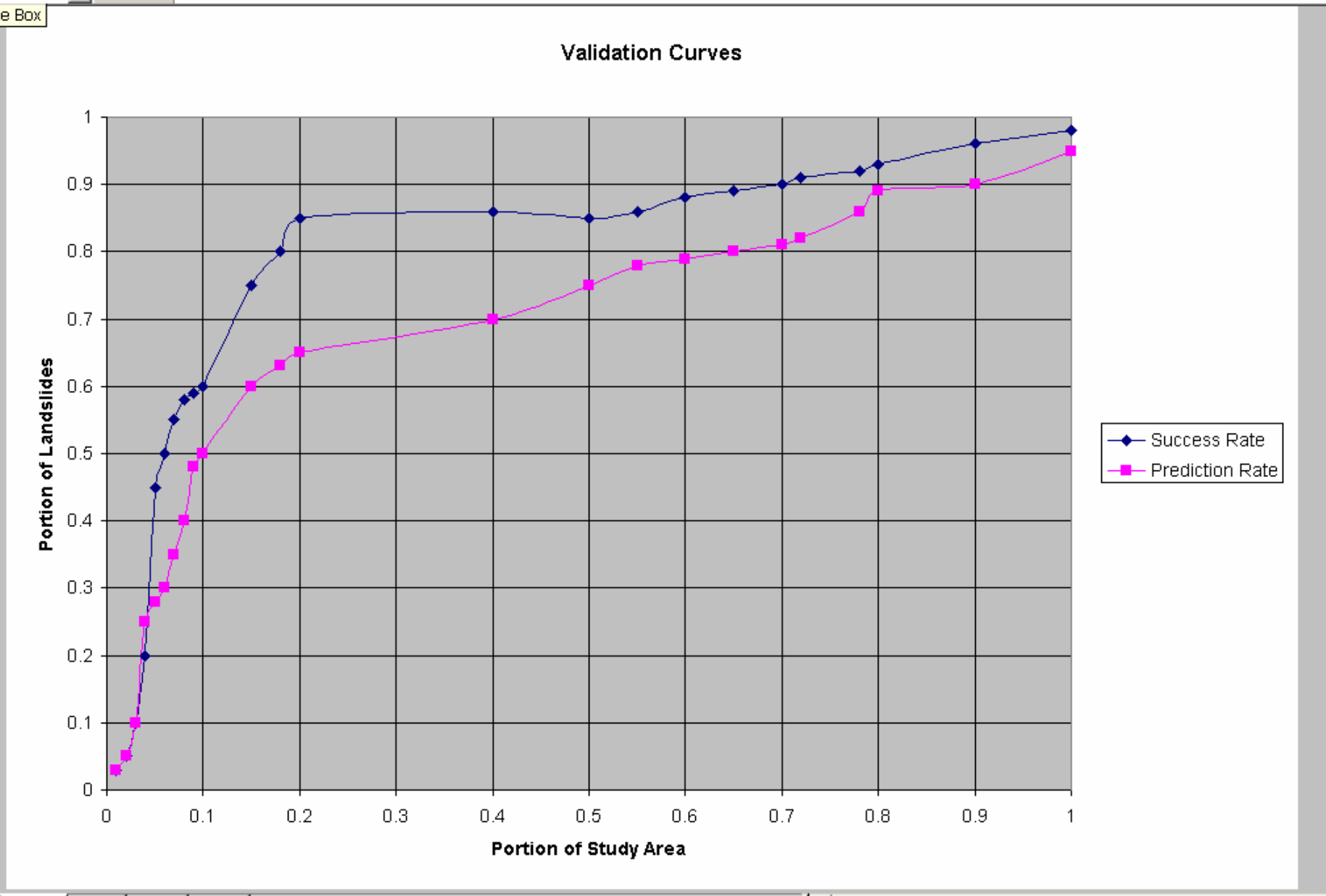
Rank from 0 to 1 with 1 being the most susceptible to sliding

100,000 pixels least susceptible 1/100,000 most susceptible 100,0000/100,000

Validation

1. Divide the landslides by time, space or randomly into two groups, one for modeling and one for validation.
2. Construct a prediction model and generate a prediction image using the landslides from the model group. Determine the success rate curve.
3. Compare the distribution of the landslides in the validation group with the prediction image and determine the the prediction-rate curve.


Validation Curves
Portion of Landslides
Portion of Study Area
Success Rate
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Validation Curves
Portion of Landslides
Portion of Study Area
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Success Rate
Prediction Rate

$$\frac{\text{Area of New Landslides by Class}}{\text{Total Area of New Landslides}} \times 100 = \%\ \text{Area of New Landslides by Class}$$