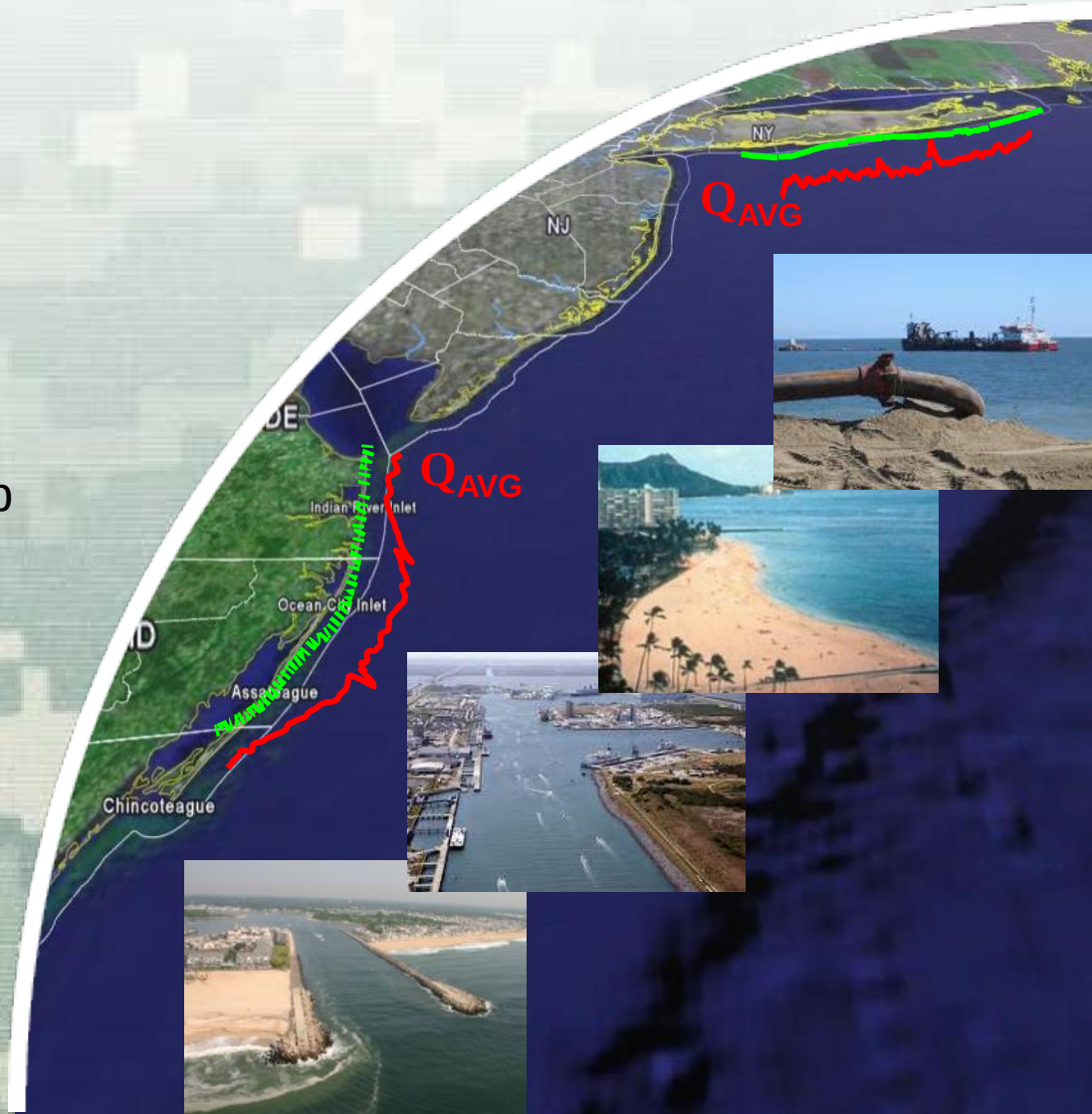
Watershed Sediment Studies

Chuck Downer, PhD, PE, PMP
Watershed Systems Group USACE ERDC CHL



RSM and EWN Inland Workshop
29 April – 1 May 2014
Omaha, Nebraska

US Army Corps of Engineers
BUILDING STRONG®

Need for Watershed Sediment Analysis

- Watershed analysis can help to determine the quantity and sources of sediment loading.
- Helpful for locating and designing sediment abatement features to control sediments at or near the source.
- The approach is valuable regardless of the sediment related concern:
  - Erosion
  - Loss of reservoir storage
  - River shoaling
  - Water quality

Basic Approach

Gather Information

Observed data help us to understand the current condition of the watershed and potential sources, determine parameters for modeling, and tune model parameters.

- Acquire adequate observed data for rainfall, flow, and sediment load/concentration
- Acquire adequate spatial information related to
  - Soils
  - Land use/disturbance
  - Impervious areas
  - Elevations
  - Streams

Basic Approach

Develop Analytical Tool

A physics based analytical model helps us understand the dominant processes, locate sources, make predictions, and analyze abatement measures.

- Develop physics based model of the watershed/study area
- Assign parameters based on physical conditions such as soil type and land use
- Calibrate parameters based on observed data

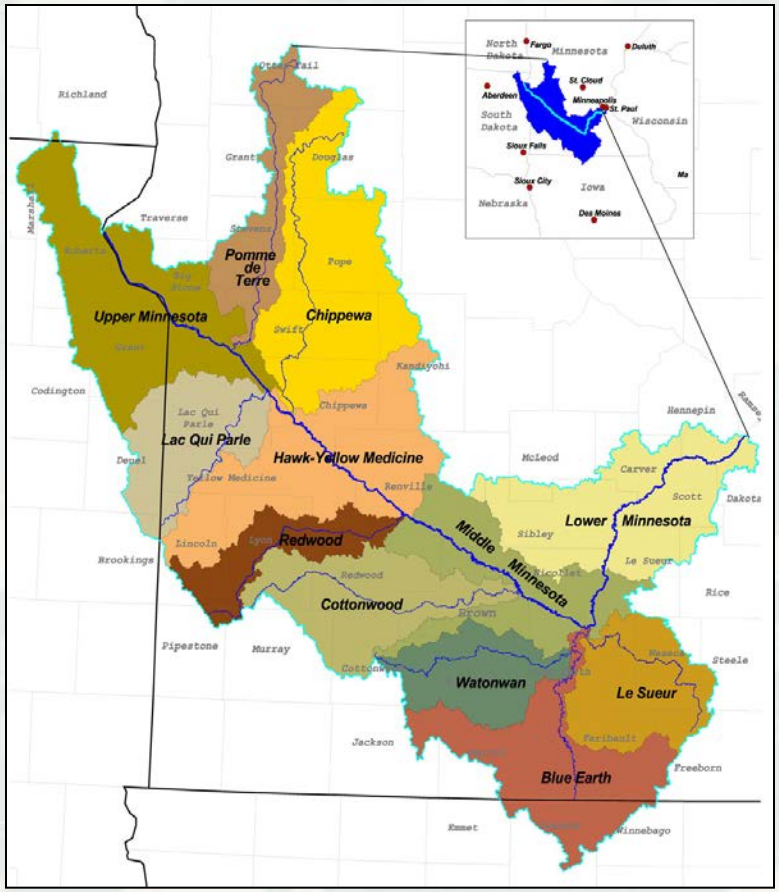
Basic Approach

Analysis

- Simulate conditions of concern
  - MPF
  - Long term simulation
  - Future conditions
  - With project conditions
- Determine loading
- Identify sources
- Design potential abatement measures as needed
- Test in model for effect
- Adjust abatement measures as needed to achieve desired result

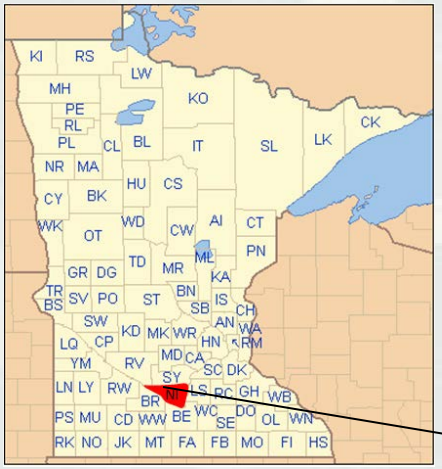
Minnesota River Study

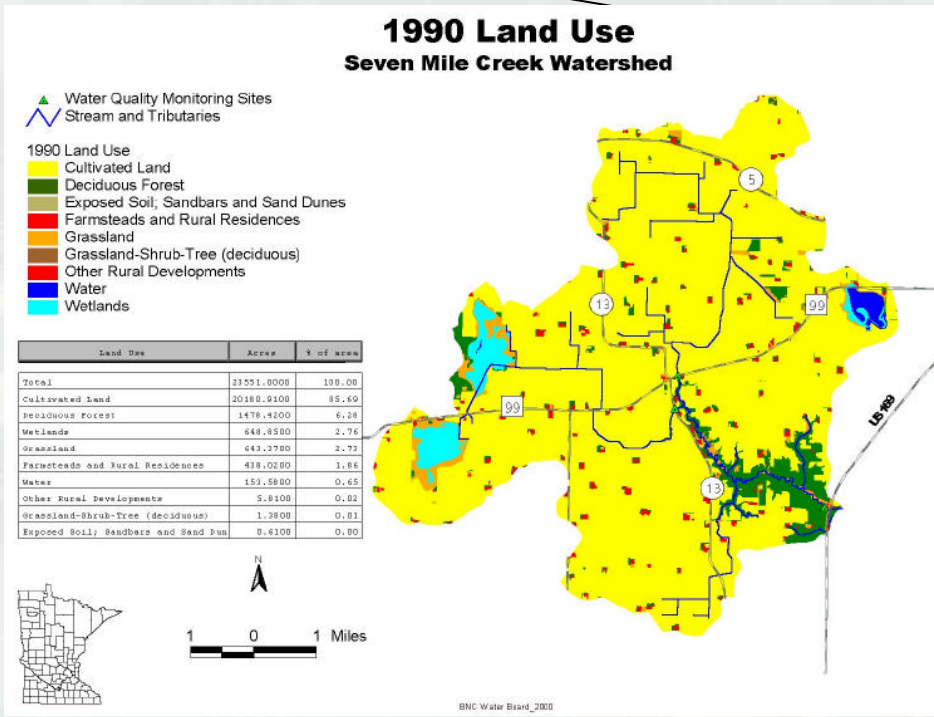
- In the Minnesota River Basin changing farming practices and weather patterns are resulting in increased erosion and reduced water quality.
- A watershed study is aimed at identifying the source of problems and assess potential abatement measures



7 Mile Creek Watershed

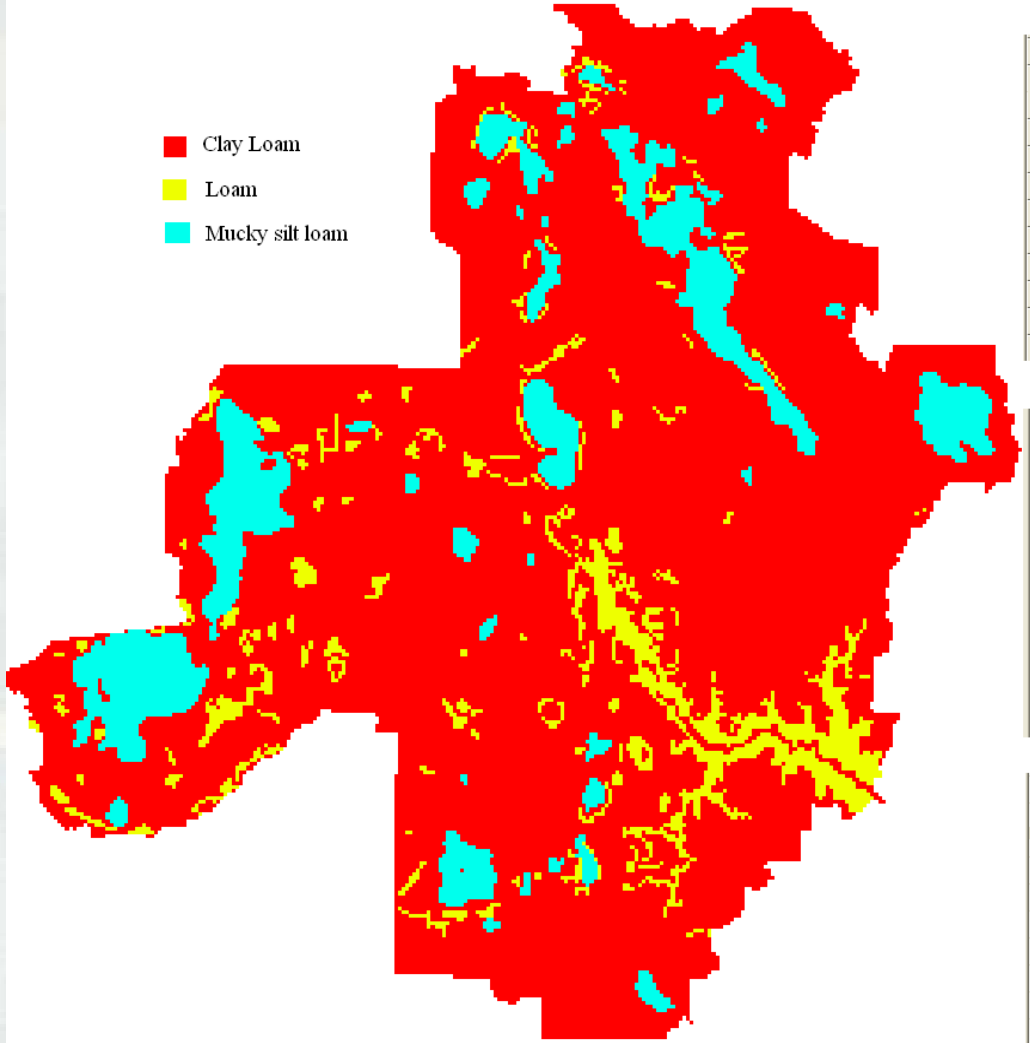
- One of two sub-basins currently being simulated with physics-based approach.
- 98 Km^2 basin
- Primarily agricultural land use.





Land Use	Acres	% of area
Total	23551.0000	100.00
Cultivated Land	20180.9100	85.69
Deciduous Forest	1478.4200	6.28
Wetlands	648.8500	2.76
Grassland	643.3700	2.73
Farmsteads and Rural Residences	438.0200	1.86
Water	153.5800	0.65
Other Rural Developments	5.8100	0.02
Grassland-Shrub-Tree (deciduous)	1.3800	0.01
Exposed Soil; Sandbars and Sand Dun	0.6100	0.00

Heavy Poorly Drained Soils



Top Layer

ID	2	3	5
Description	clay loam	loam	mucky silt loam ...
Hydraulic conductivity (cm/hr)	0.200000	1.320000	0.680000
Pore distribution index (cm/cm)	0.390000	0.434000	0.486000
Capillary head (cm)	20.880000	8.890000	16.680000
Porosity (m^3/m^3)	0.464000	0.463000	0.501000
Field capacity (m^3/m^3)	0.318000	0.270000	0.330000
Wilting point (m^3/m^3)	0.117000	0.117000	0.117000
Residual saturation (m^3/m^3)	0.075000	0.027000	0.015000
Initial soil moisture (m^3/m^3)	0.300000	0.200000	0.300000
Depth (cm)	43.180000	35.560000	20.320000

Middle Layer

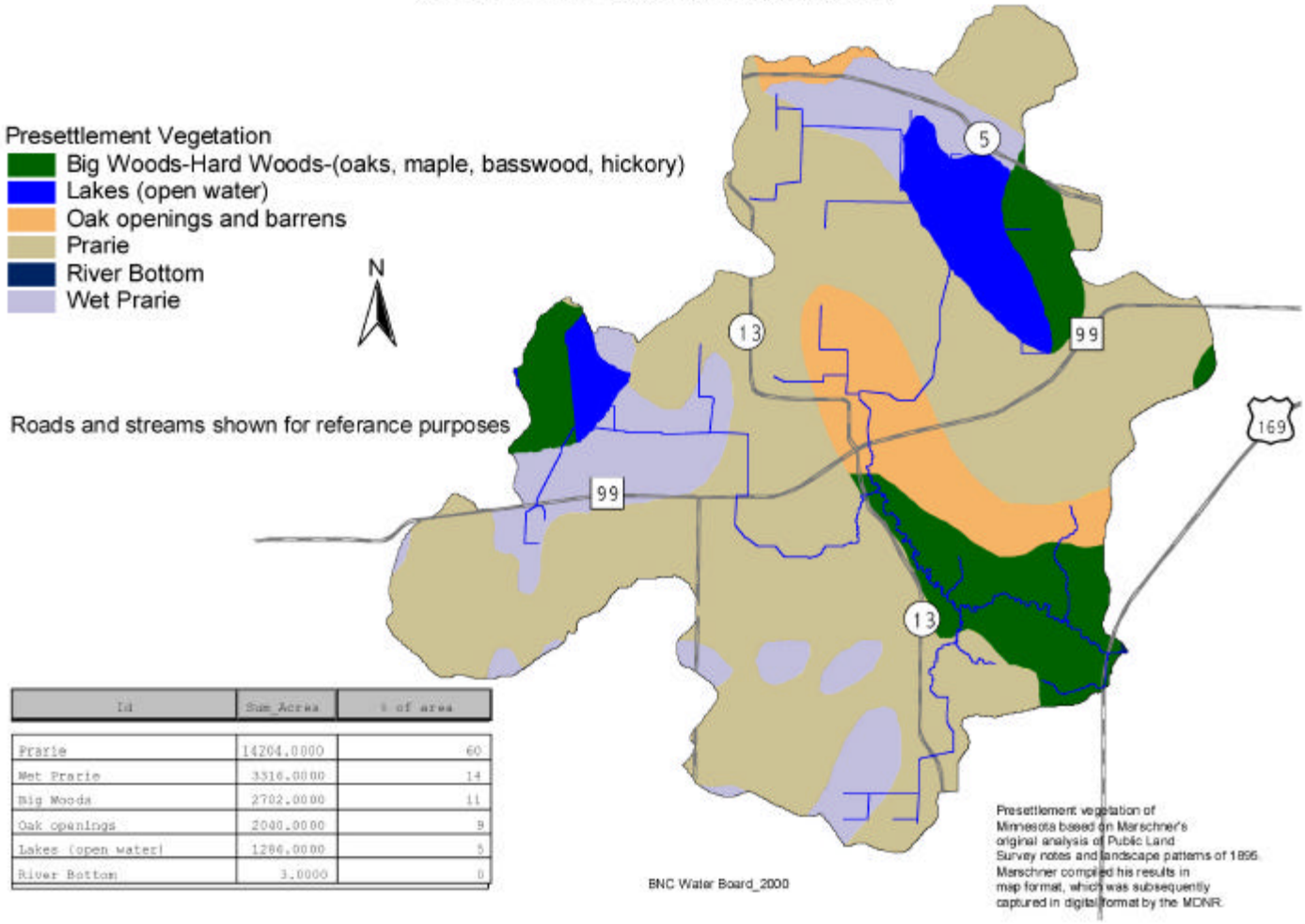
ID	2	3	5
Description	clay loam loam silty clay loam	clay loam loam	clay loam silty clay loam silt loam
Hydraulic conductivity (cm/hr)	0.573000	0.760000	0.360000
Pore distribution index (cm/cm)	0.418000	0.412000	0.436000
Capillary head (cm)	19.020000	14.885000	21.620000
Porosity (m^3/m^3)	0.466000	0.463000	0.478000
Field capacity (m^3/m^3)	0.318000	0.294000	0.338000
Wilting point (m^3/m^3)	0.174000	0.157000	0.179000
Residual saturation (m^3/m^3)	0.047000	0.051000	0.043000
Initial soil moisture (m^3/m^3)	0.300000	0.250000	0.300000
Depth (cm)	43.180000	43.180000	55.880000

Bottom Layer

ID	2	3	5
Description	clay loam loam ...	clay loam loam ...	clay loam silty clay loam silt loam ...
Hydraulic conductivity (cm/hr)	0.760000	0.760000	0.360000
Pore distribution index (cm/cm)	0.412000	0.412000	0.436000
Capillary head (cm)	14.885000	14.885000	21.620000
Porosity (m^3/m^3)	0.463000	0.463000	0.478000
Field capacity (m^3/m^3)	0.294000	0.294000	0.338000
Wilting point (m^3/m^3)	0.157000	0.157000	0.179000
Residual saturation (m^3/m^3)	0.051000	0.051000	0.043000
Initial soil moisture (m^3/m^3)	0.250000	0.250000	0.300000
Depth (cm)	66.040000	73.660000	76.200000

Presettlement Vegetation

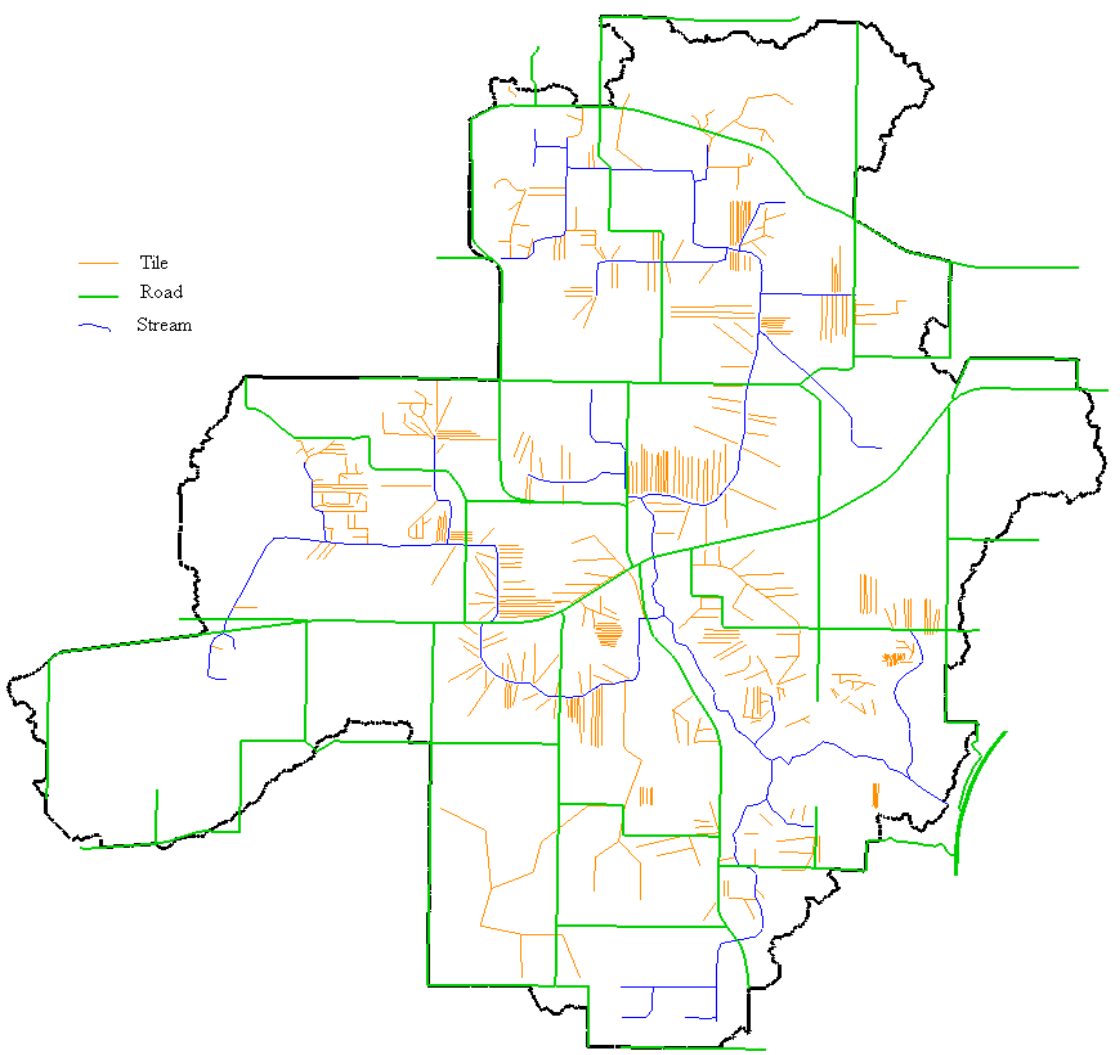
Seven Mile Creek Watershed



Id	Sum_Acres	% of area
Prarie	14204.0000	60
Wet Prarie	3316.0000	14
Big Woods	2702.0000	11
Oak openings	2000.0000	9
Lakes (open water)	1286.0000	5
River Bottom	3.0000	0

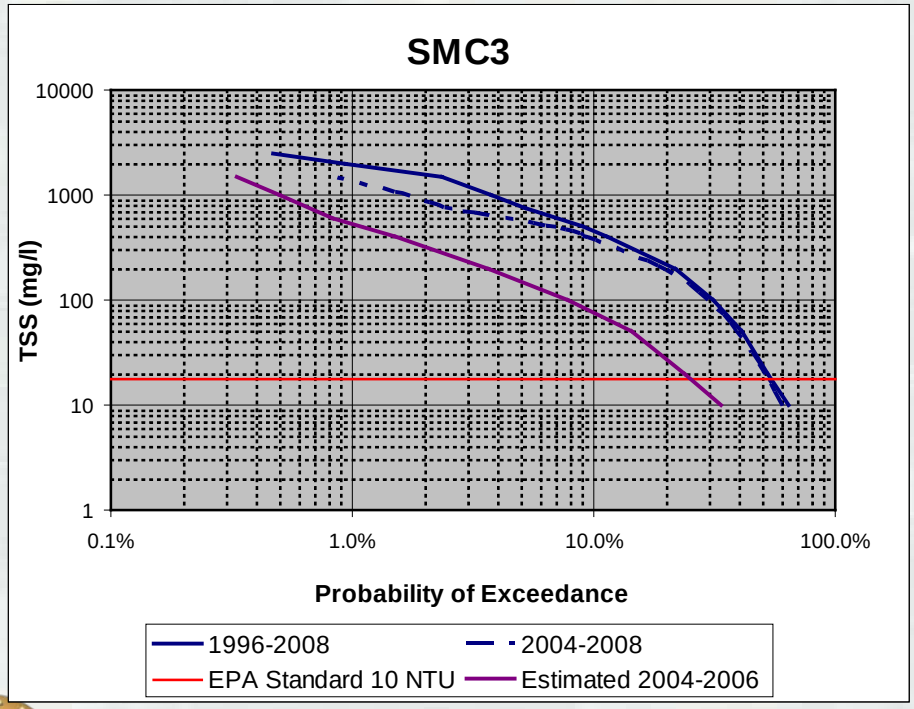
Drainage System

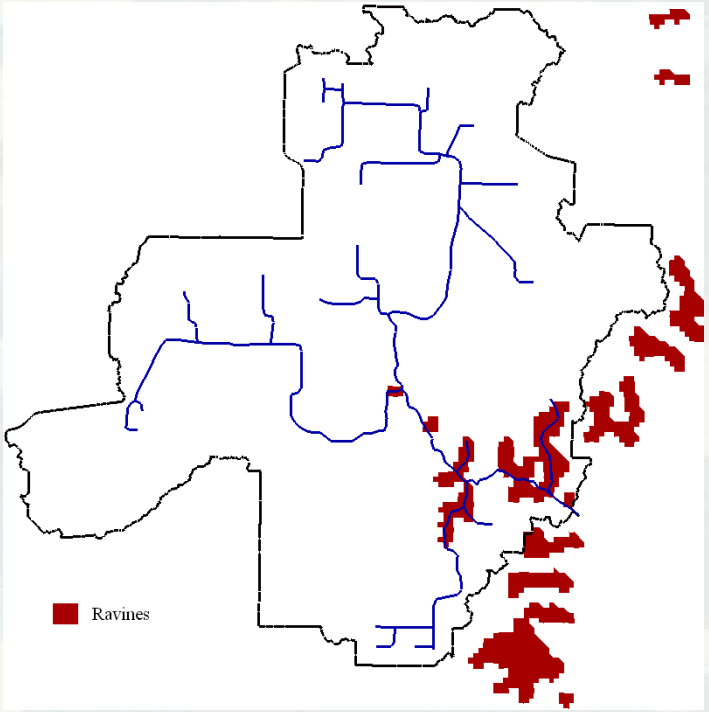
- Natural drainage not adequate for row crop agriculture.
- Drained by extensive ditch and tile system.



Issues

- Erosion
- Ravines
- Poor water quality

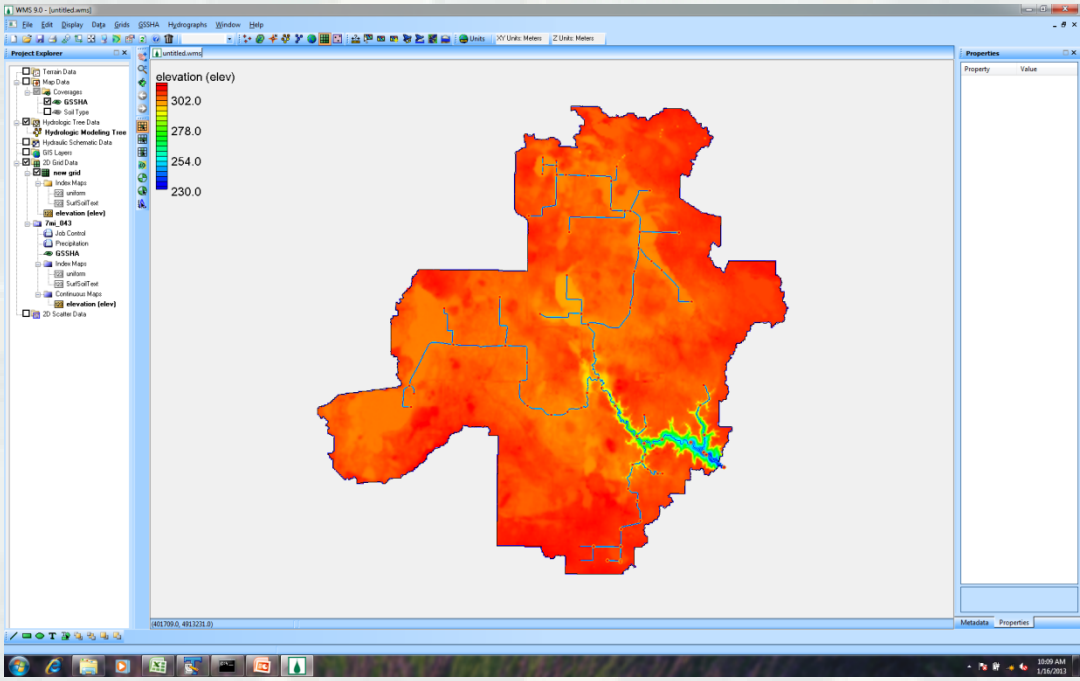




Observed Ravine Locations

7 Mile Creek Model

- 50m grid cells
- 39,142 grid cells
- 91 stream links
- Approximately 1000 subsurface drainage nodes



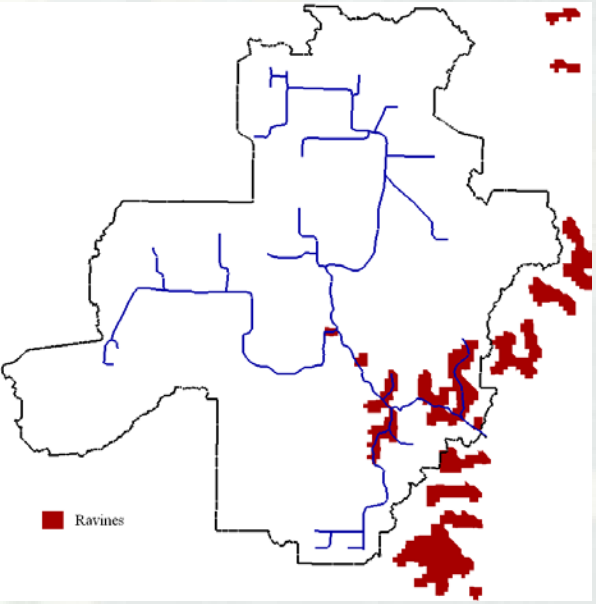
Soil Erosion

Soil erosion model was developed using the soil erosion properties (texture) as per the soil map.

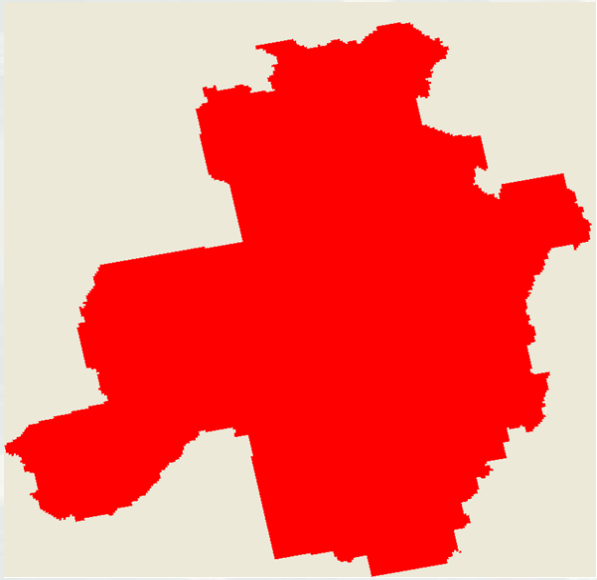
ID	2	3	5
Description1	clay loam ...	loam ...	mucky silt lo...
Coefficient for detachment by rainfall (1/J)	0.025000	0.025000	0.025000
Rill erodibility coefficient (s/m)	0.011500	0.011500	0.011500
Rill erodibity exponent (dimensionless)	1.000000	1.000000	1.000000
Critical rill detachment (Pa)	3.100000	3.100000	3.100000
Erodibity coefficient (dimensionless)	0.200000	0.200000	0.200000
Fraction of Sand	0.400000	0.450000	0.200000
Fraction of Silt	0.250000	0.350000	0.150000
Fraction of Clay	0.350000	0.200000	0.650000

The soil erosion parametric values

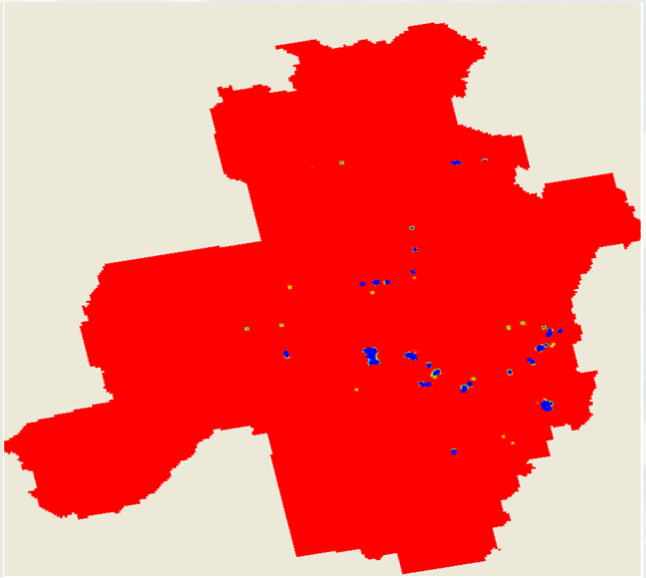
Interim Findings: Preliminary simulations suggest tile drainage is major source of stream flow, sediment load, and gully erosion.



Observed



Simulated without tile drainage



Simulated with tile drainage

Kaukonahua Watershed

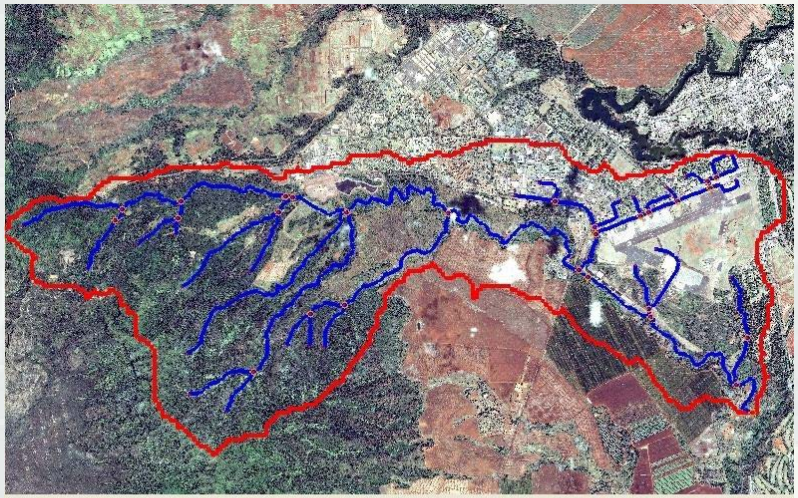
- The Kaukonahua stream, located on the Hawaii island of Oahu, drains into Pearl Harbor, a water body not meeting EPA and state water quality criteria.
- The EPA has determined the loading that will allow the water body to meet it's designated uses, and is in the process of assigning loads to various NPDES permit holders.
- ERDC is determining loadings for Tri-Services installations and recommending best management practices (BMPs) to be implemented at each location.

Location

Kawela Bay
Pupukea
Laie
Hauula
Kaaawa
Makuleia
Waialua
930
80
Schofield Barracks, HI
Schofield Barracks
Waikane
Makaha
782
Waianae
750
Mililani Town
Kaneohe Station
Maili
Waipio
Waimalu
Kaneohe
Kailua
Nanakuli
Wipahu
99
Halawa
63
83
Maunawili
Makakilo City
Aiea
Aiea Villages
Hickam Housing
Waimanalo
61
Honolulu
Barbers Point Housing
Ewa Beach
64
92
72
21.7°N
21.6°N
21.5°N
21.4°N
21.3°N
158.4°W
158.3°W
158.2°W
158.1°W
158.0°W
157.9°W
157.8°W

Setting

- Tropical setting with strong wet and dry season.
- Weathered basalt soils.
- Steep slopes in uplands.
- Various land uses
  - Firing ranges
  - Airfields
  - Barracks

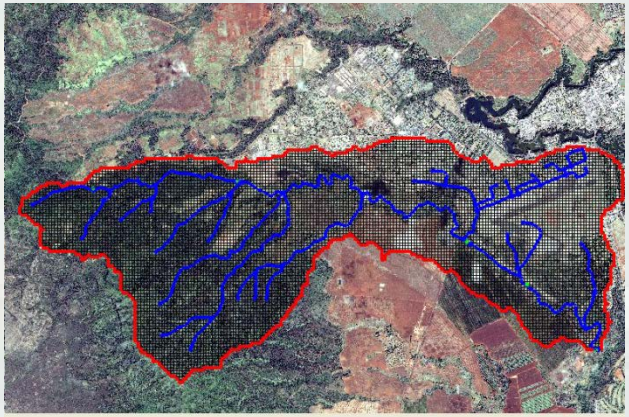


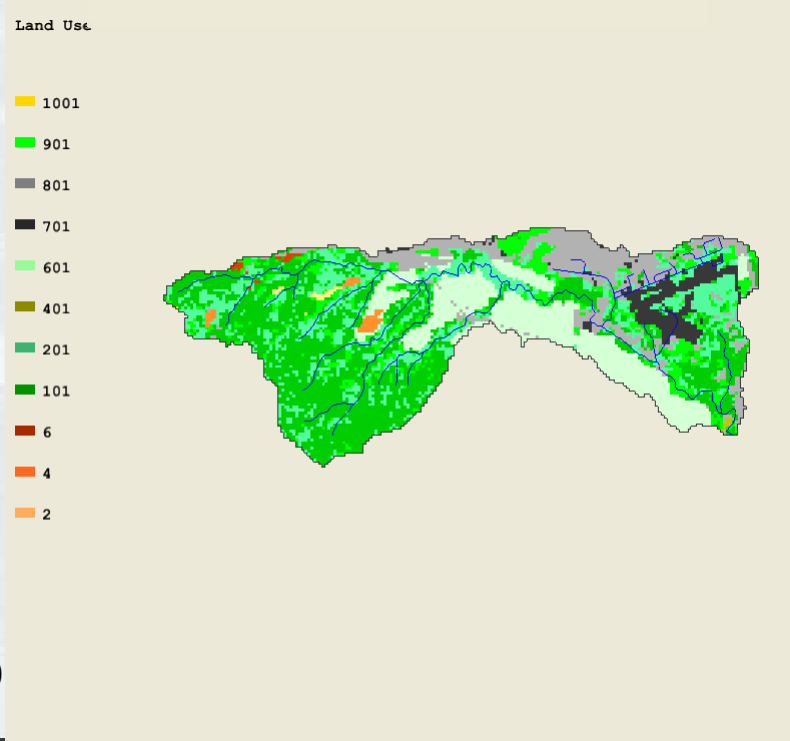
Watershed Sampling

- Rainfall
- Stream flow
- Total suspended solids
- Total nitrogen
- Standard water quality variables
- Sampling at installation inflow and outflow points

Watershed Models

- GSSHA hydrologic models at multiple installations and sub-basins of the Kaukonahua watershed.
- Calibrated to flow and TSS
- Used to determine loading, sources, and recommend BMPs



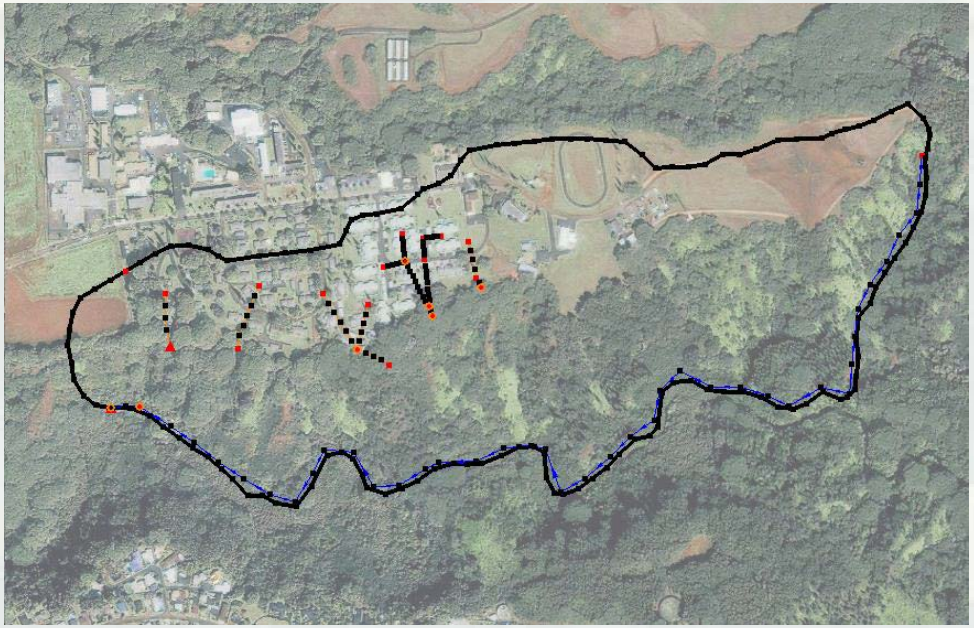


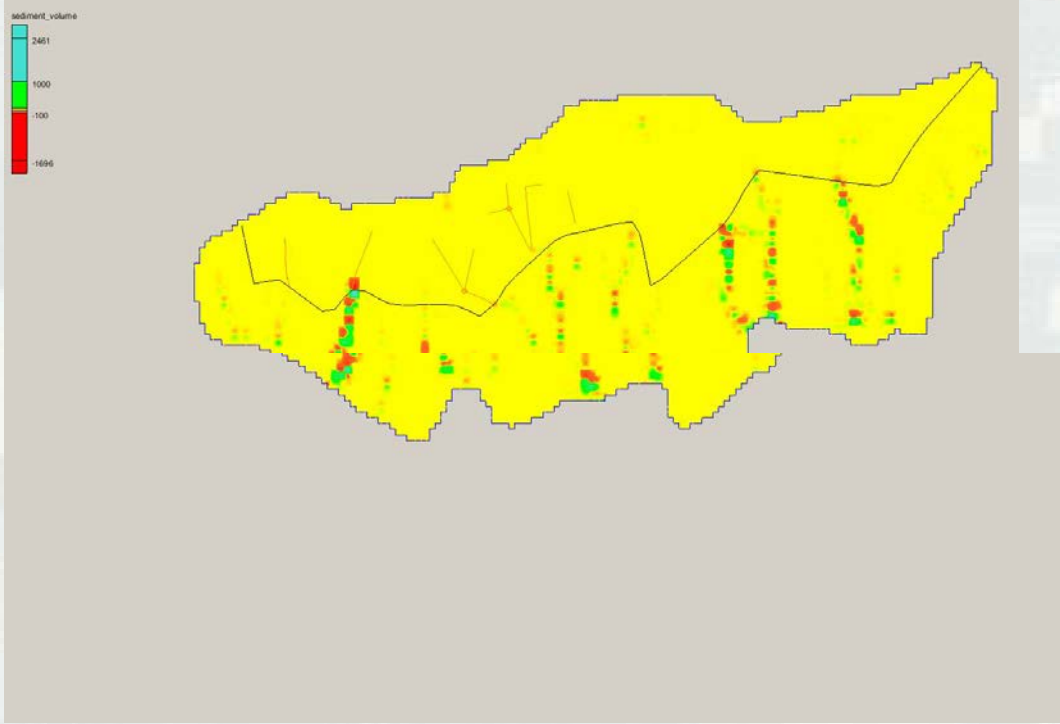
Preliminary Findings

- In the Upper Kaukonahua Watershed sediment comes from disturbed areas and from unprotected roadways in steep areas.
- In Waikele Watershed the primary sediment source is from erosion of ditches, swales and other concentrated flow areas.

NCTAMS

- Primary source of sediments is erosion of hill slopes below concentrated flow areas.





Conclusions

- Watershed studies can be used to determine sediment loadings, identify sources, and identify, design and assess appropriate BMPs for the identified problems.
- Because every situation is different, it is necessary to identify the problem and select and design BMPs that will work for the particular problem.
- A physics based modeling approach is useful because it can used to help understand the processes that control the sediment process, identify source sources and select and design appropriate BMPs.