The WIN System – A Suite of Tools for Resource Management Decision Making

Virtual EnviroTech 2020
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Multiple pressures on landscape

- **Agriculture/Forestry:**
  - ➢ **Crop/animal production, logging, forestry roads**
- **Natural disturbance:**
  - ➢ **Floods, wildfire, MPB**
- **Oil and Gas:**
  - ➢ **Well pads**
  - ➢ **Seismic lines**
  - ➢ **Oilsands**
- **Recreation:**
  - ➢ **Off Highway Vehicles**
  - ➢ **Camping**
  - ➢ **Fishing and Hunting**

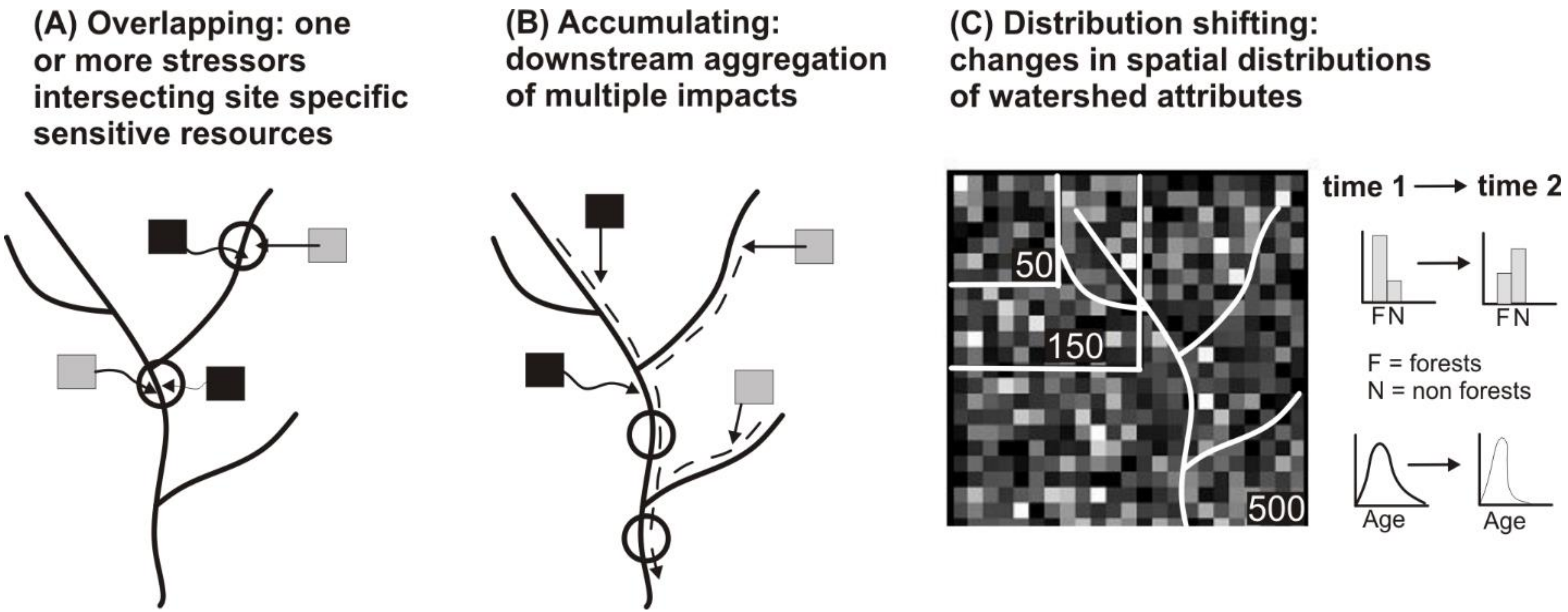
Management of cumulative watershed impacts

- **Legislation**
  - **Nutrient management policy**
  - **Forest management policy**
  - **Water for Life Strategy**
  - **Land Use Framework**
- **Using beneficial management practices (rules)**
- **Monitoring & compliance**
- **Supported with tools such as models.**

Cumulative Watershed Effects

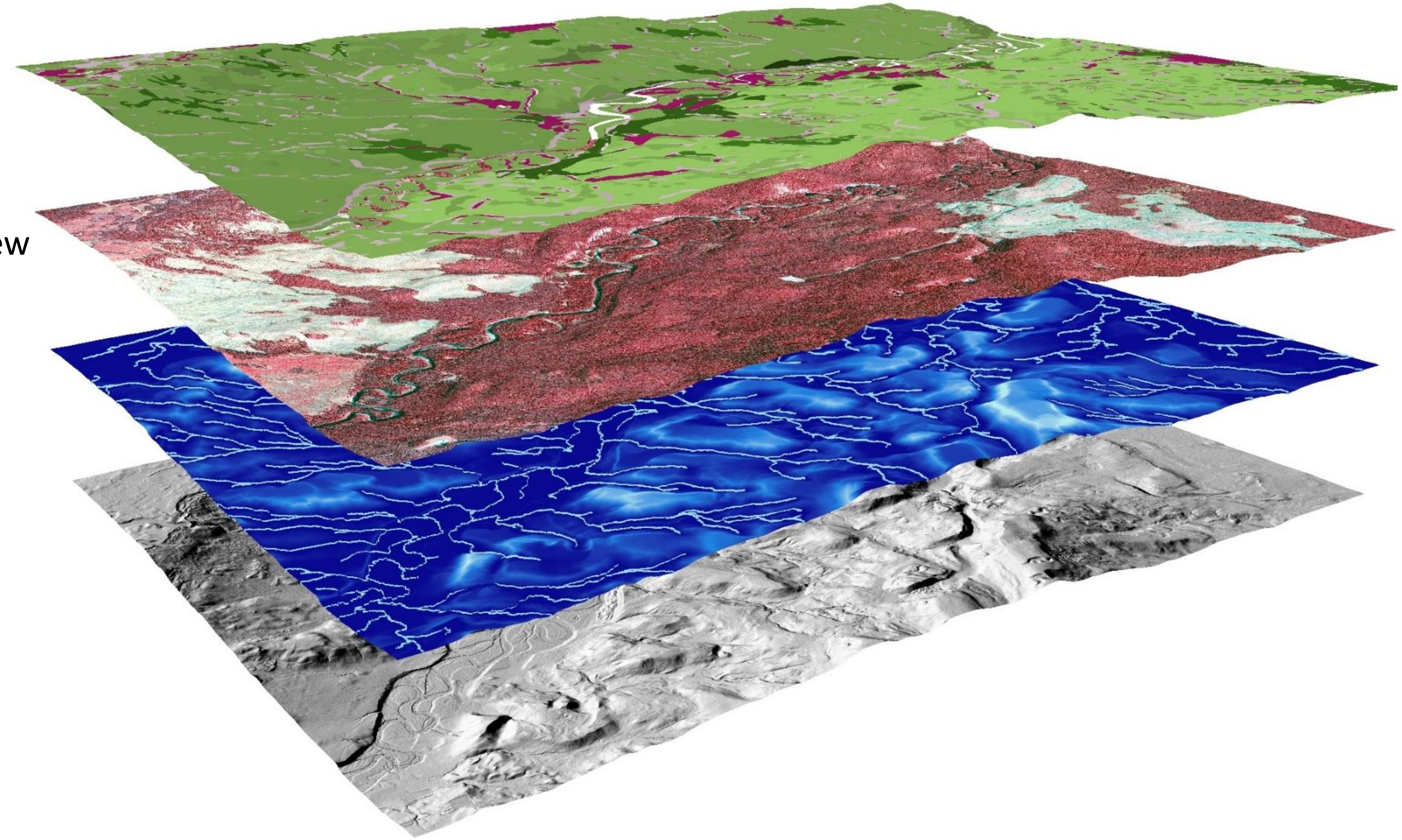
- Interactions between natural processes (eg floods, fires, pest/disease outbreaks, landslides, etc) and land uses (eg energy development, forest harvesting, farming, transportation, urban development, etc) that can negatively affect ecosystem processes both in space and time (Reid, 1998; MacDonald, 2000; Noble, 2011)

Three forms of cumulative effects analysis



Spatial decision support tools

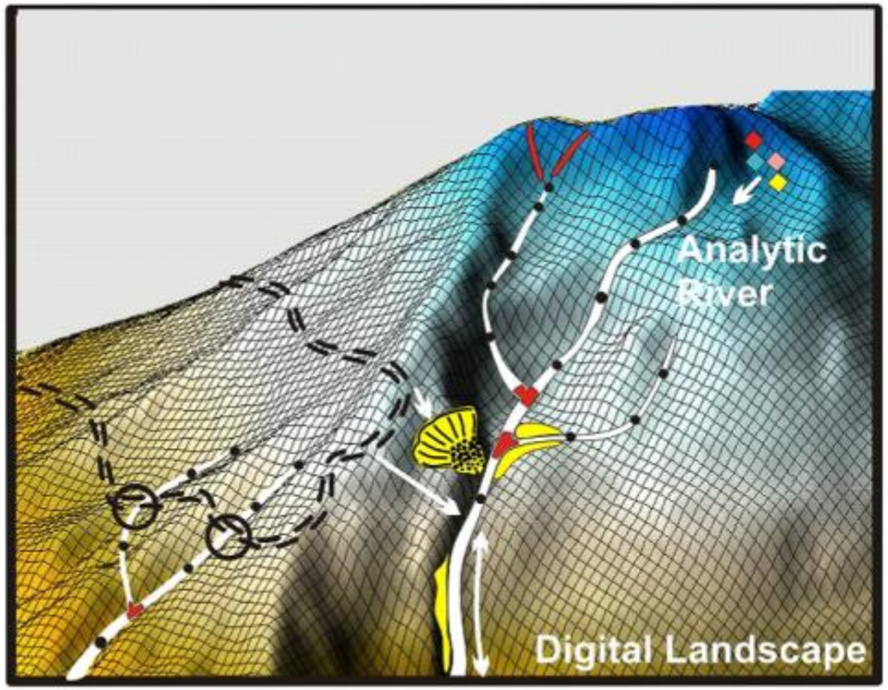
Can we integrate a number of in-house and third-party data (e.g. netmap) to create a few simple layers for field staff to use for risk assessment?



Terrain Works

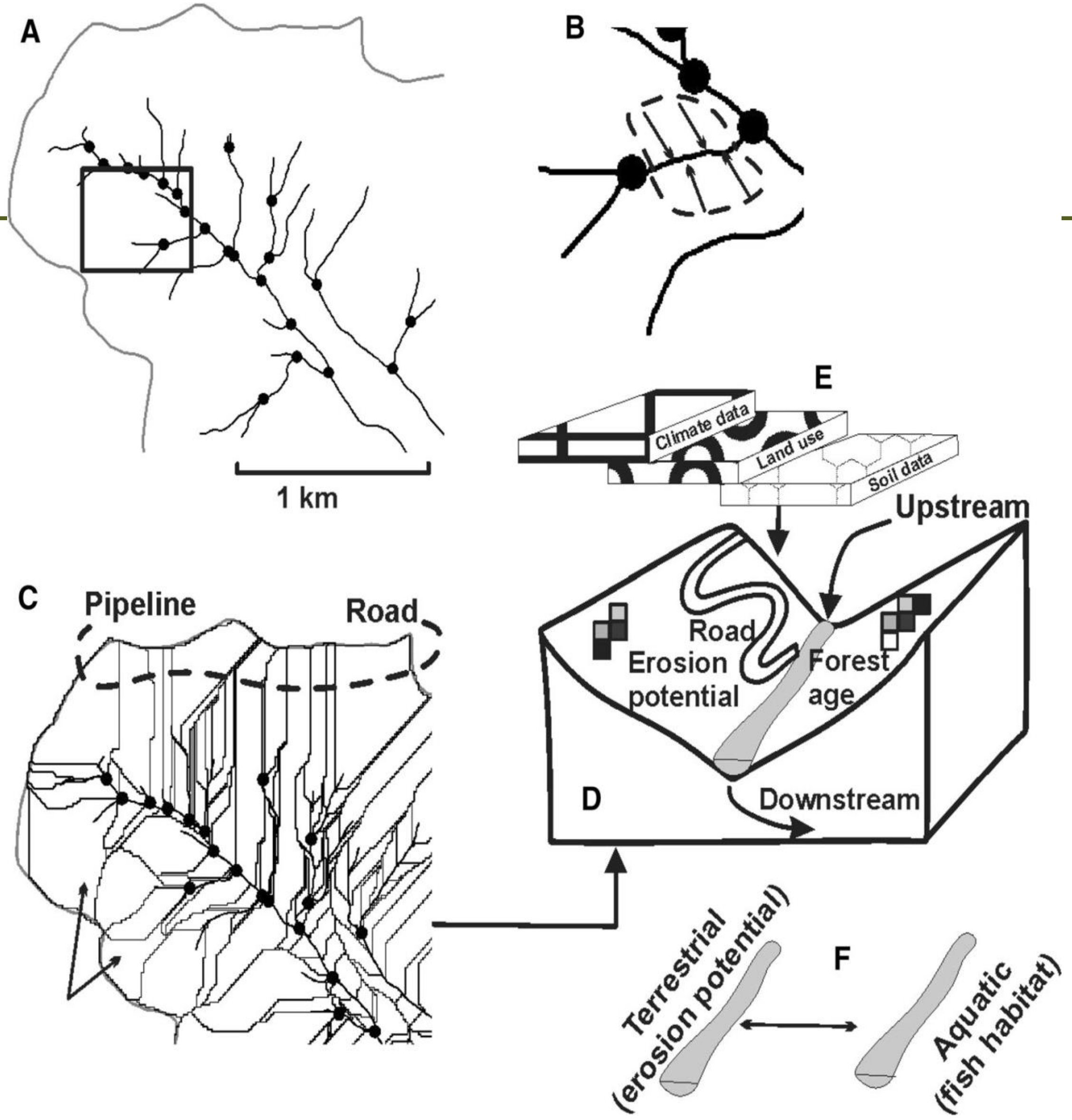
NetMap Desktop Watershed Analysis

- Predict road/pipeline drainage diversion
- Analyze road surface erosion & delivery
- Evaluate road stability
- Calculate habitat length & quality above all crossings
- Identify roads in floodplains/wet zones
- Rank subbasins by any attribute

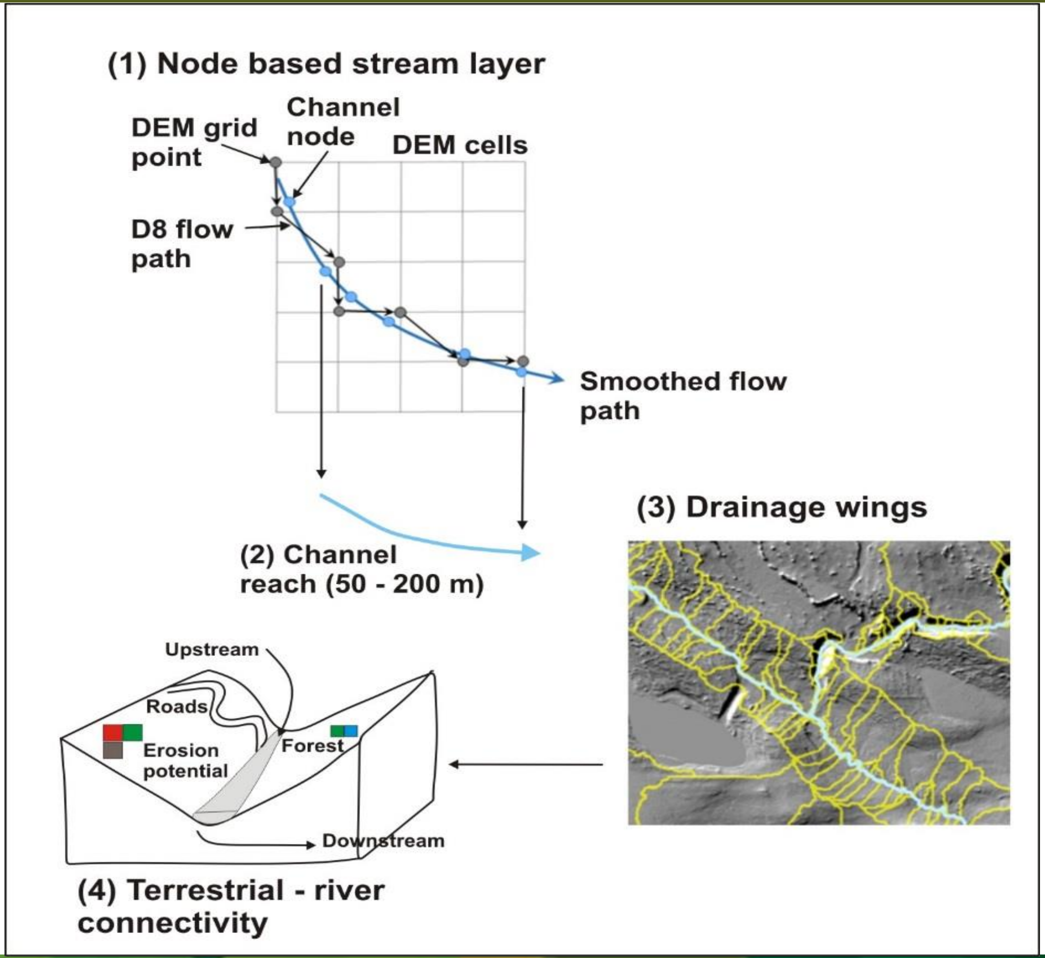


- Simulate hillside surface erosion & delivery
- Predict landslide potential/sediment delivery
- Map debris flow/ gully potential
- Consider radiation loading
- Evaluate riparian manage
- Map channel types/ fish habitat
- Predict floodplains, wet areas, terraces fans

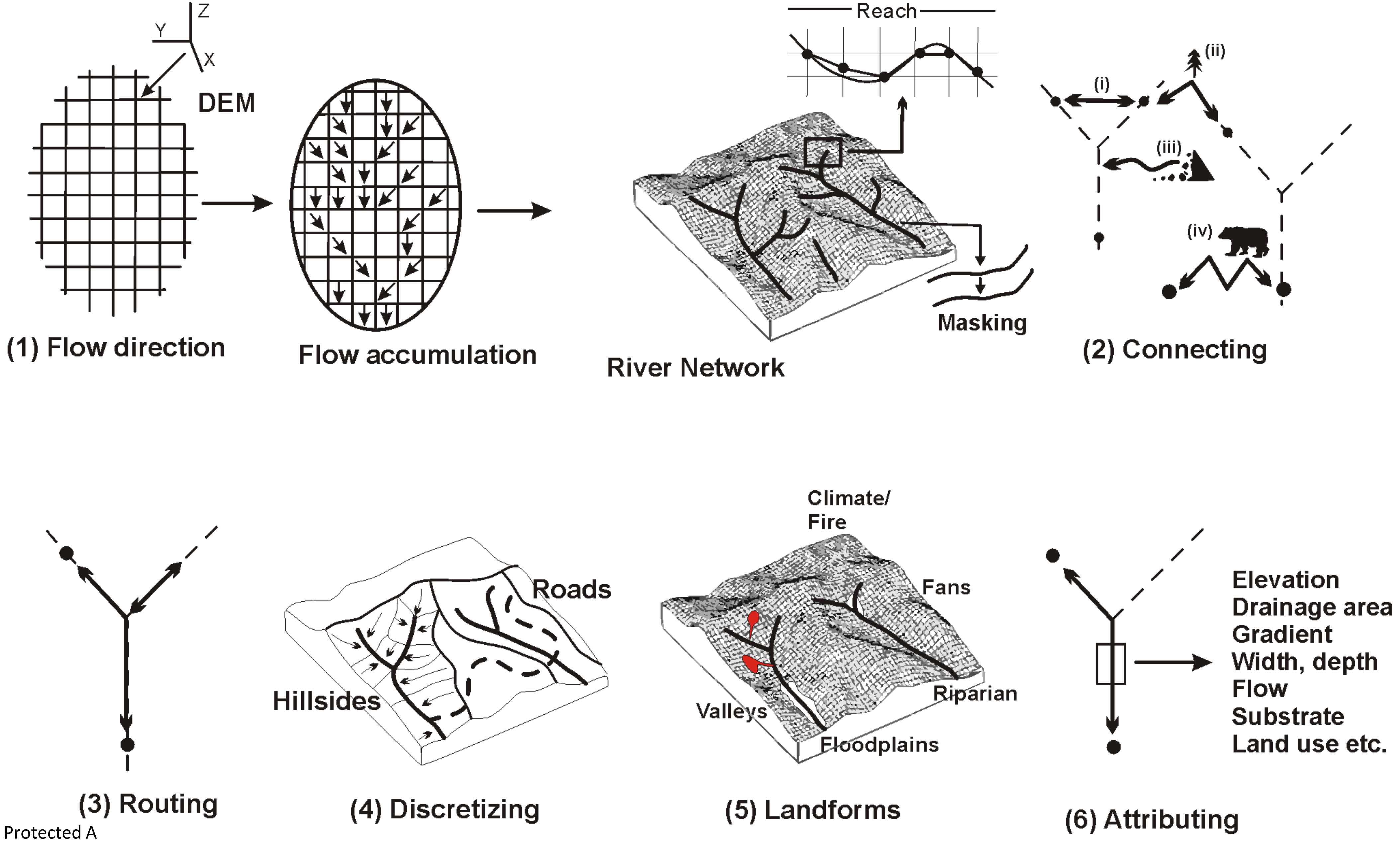
Virtual watershed



Node-based synthetic stream layer with drainage wings

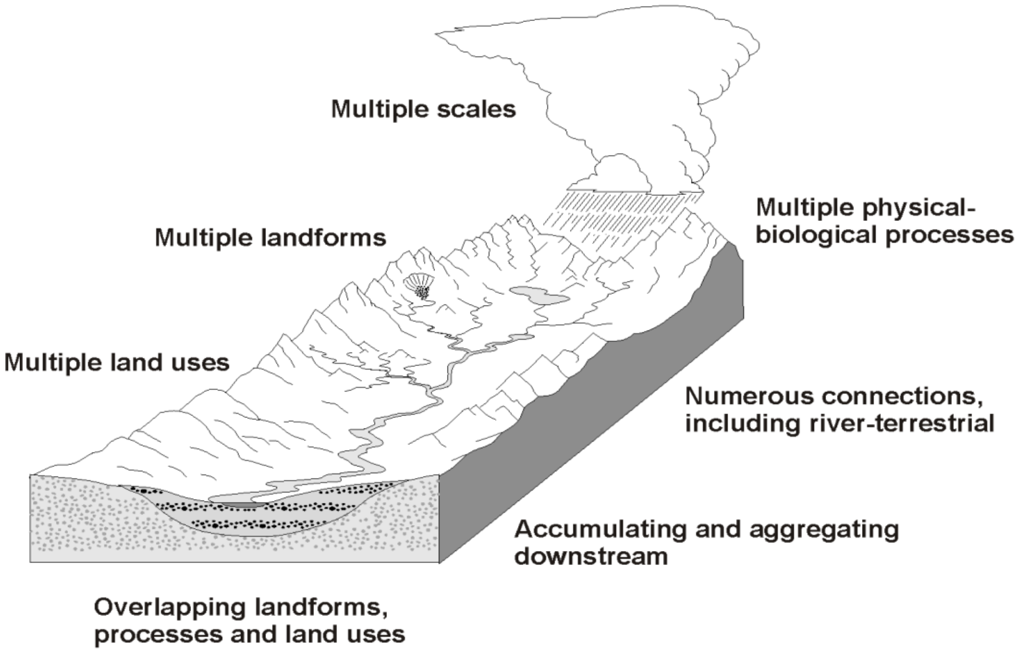


Building Virtual Watersheds



Elements of WIN-System

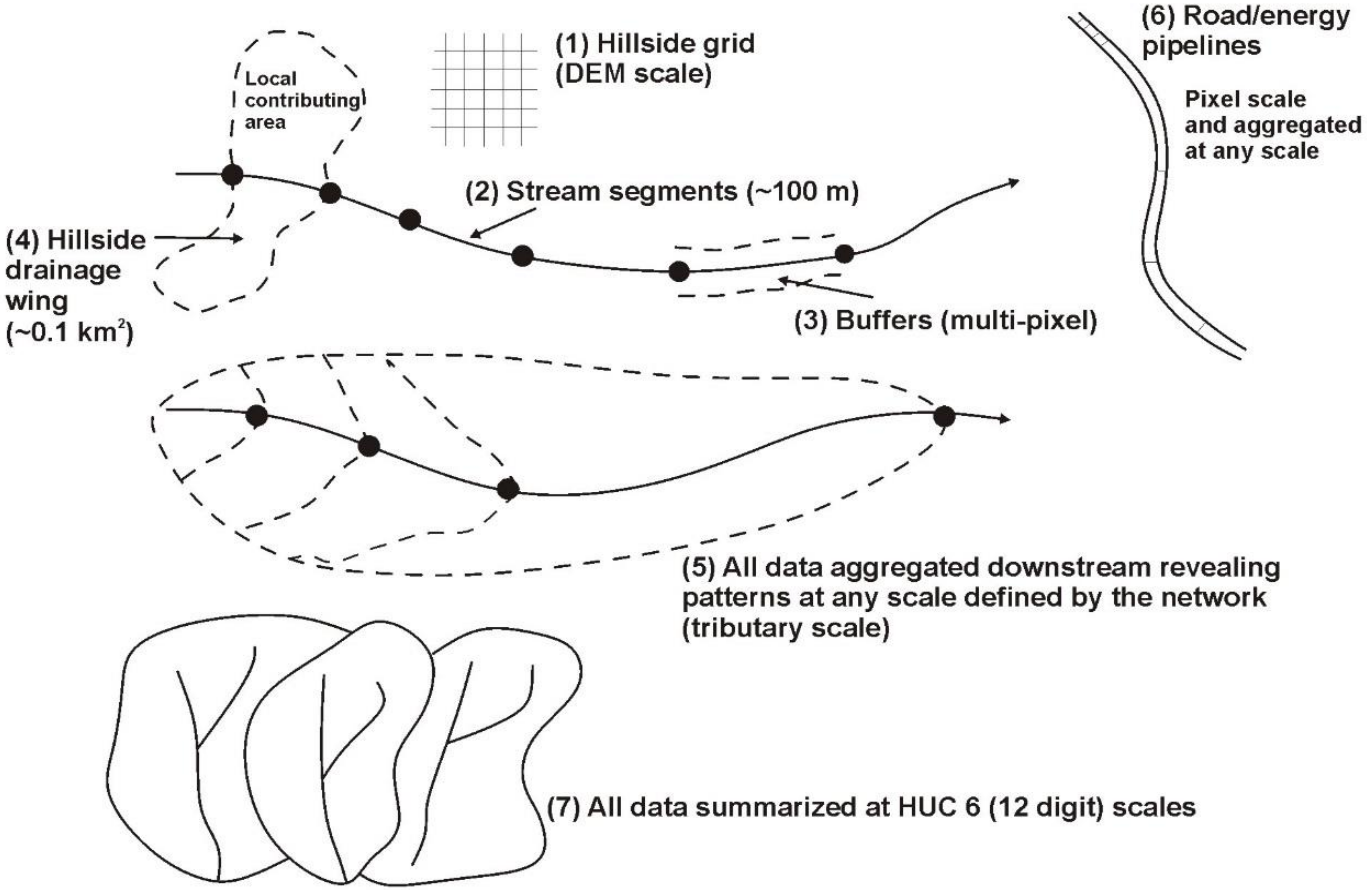
Key Elements of Cumulative Watershed Effects Analysis and Resource Use Decision Support



Analysis tools

- Up to 100 analysis tools can be incorporated into the WIN-System
- Calculate channel gradient
- Aquatic/terrestrial habitat assessment – quality and diversity
- Fluvial processes assessment
- Riparian condition assessment
- Erosion assessment
- Layout of roads and location of stream crossings
- Wildfire impacts assessment
- Climate change vulnerability assessment

Multiple scales of analysis



Road erosion and sedimentation

Benda, L., James, C., Miller, D., Andras, K., 2019. Road Erosion and Delivery Index (READI): A Model for Evaluating Unpaved Road Erosion and Stream Sediment Delivery. JAWRA Journal of the American Water Resources Association. https://doi.org/10.1111/1752-1688.12729

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JAWRA

Road Erosion and Delivery Index (READI): A Model for Evaluating Unpaved Road Erosion and Stream Sediment Delivery

Lee Benda, Cajun James, Daniel Miller, and Kevin Andras

Research Impact Statement: A new model evaluates road network erosion and sediment delivery to streams and then prioritizes new drain and surfacing locations to optimize road–stream disconnection and reduce sediment delivery.

ABSTRACT: The Road Erosion and Delivery Index (READI) is a new geographic information system–based model to assess erosion and delivery of water and sediment from unpaved road networks to streams. READI quantifies the effectiveness of existing road surfacing and drain placements in reducing road sediment delivery and guides upgrades to optimize future reductions. Roads are draped on a digital elevation model and parsed into hydrologically distinct segments. Segments are further divided by engineered drainage structures. For each segment, a kinematic wave approximation generates runoff hydrographs for specified storms, with discharge directly to streams at road–stream crossings and onto overland-flow plumes at other discharge points. Plumes are attenuated by soil infiltration, which limits their length, with delivery occurring if plumes intersect streams. Sediment production and sediment delivery can be calculated as a relative dimensionless index. READI predicts only a small proportion of new drains and new surfacing results in the majority of sediment delivery reductions. The model illustrates how the spatial relationships between road and stream networks, controlled by topography and network geometries, influence patterns of road–stream connectivity. READI was applied in seven northern California basins. The model was also applied in a recent burn area to examine how reduced hillslope infiltration can result in increased hydrologic connectivity and sediment delivery.

(KEYWORDS: forest roads; road erosion; hydrologic connectivity; sediment; sediment delivery; BMP; wildfire; basins; industrial forest lands.)

INTRODUCTION

Unpaved roads may be a dominant source of land use–related sediment pollution with the potential to impact water quality and aquatic biota (Ketcheson and Megahan 1996; Goode et al. 2012). Such roads may present a pervasive sediment source, particularly in areas of intensive land management or oil and gas development (Luce and Wemple 2001; Buto et al. 2010). Recognizing roads as a continuing source of sediment pollution (Gucinski et al. 2001), Washington (Washington Department of Natural Resources 2001) and California (California State Board of Forestry 2013) set regulations to hydrologically disconnect forest roads from streams. Likewise, federal and state resource management agencies have specified best management practices (BMPs) to reduce road erosion and sediment delivery (e.g., Dubé et al. 2004; U.S. Forest Service 2012). Such BMPs include paving, converting native surfaces to gravel surfaces, adding drainage structures, moving roads away from

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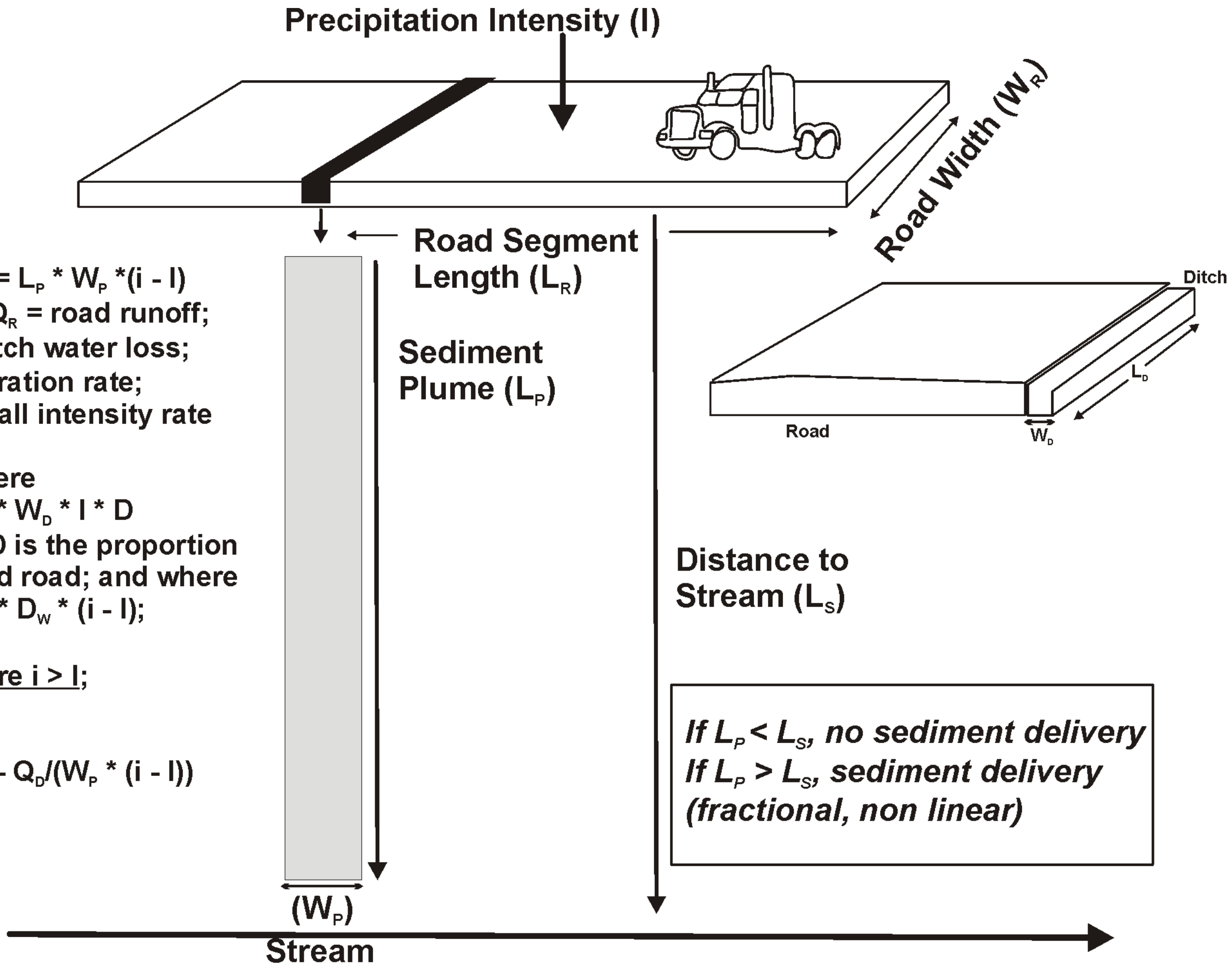
Citation: Benda, L., C. James, D. Miller, and K. Andras. 2019. "Road Erosion and Delivery Index (READI): A Model for Evaluating Unpaved Road Erosion and Stream Sediment Delivery." *Journal of the American Water Resources Association* 1–26. https://doi.org/10.1111/1752-1688.12729.

Sediment

“Sediment is largest pollutant to streams and in the absence of wildfire, forest (resource) roads are usually the main source…” (Elliot et.al, 2009)

But how do we identify and prioritize management for non-point sources at both planning & operational scales?

Road sediment delivery to streams (NetMap model)



$Q_R - Q_D = L_P * W_P * (i - I)$
where Q_R = road runoff;
Q_D is ditch water loss;
i = infiltration rate;
I = rainfall intensity rate

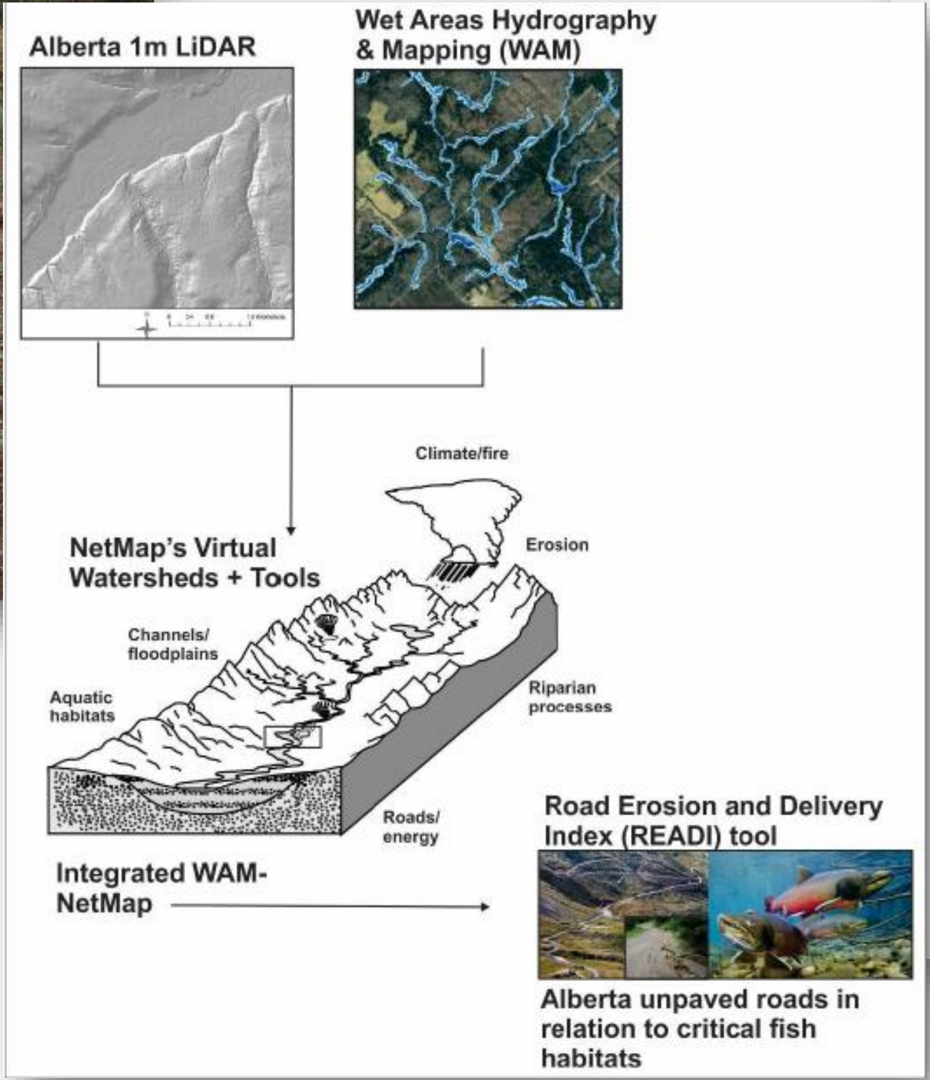
and where
$Q_R = L_D * W_D * I * D$
where D is the proportion insloped road; and where
$Q_D = D_L * D_W * (i - I)$;

<u>for where $i > I$</u>;

thus:
$L_P = Q_R - Q_D/(W_P * (i - I))$

Sediment delivery to fish habitat

Photo credit: Jared Fath, University of Alberta



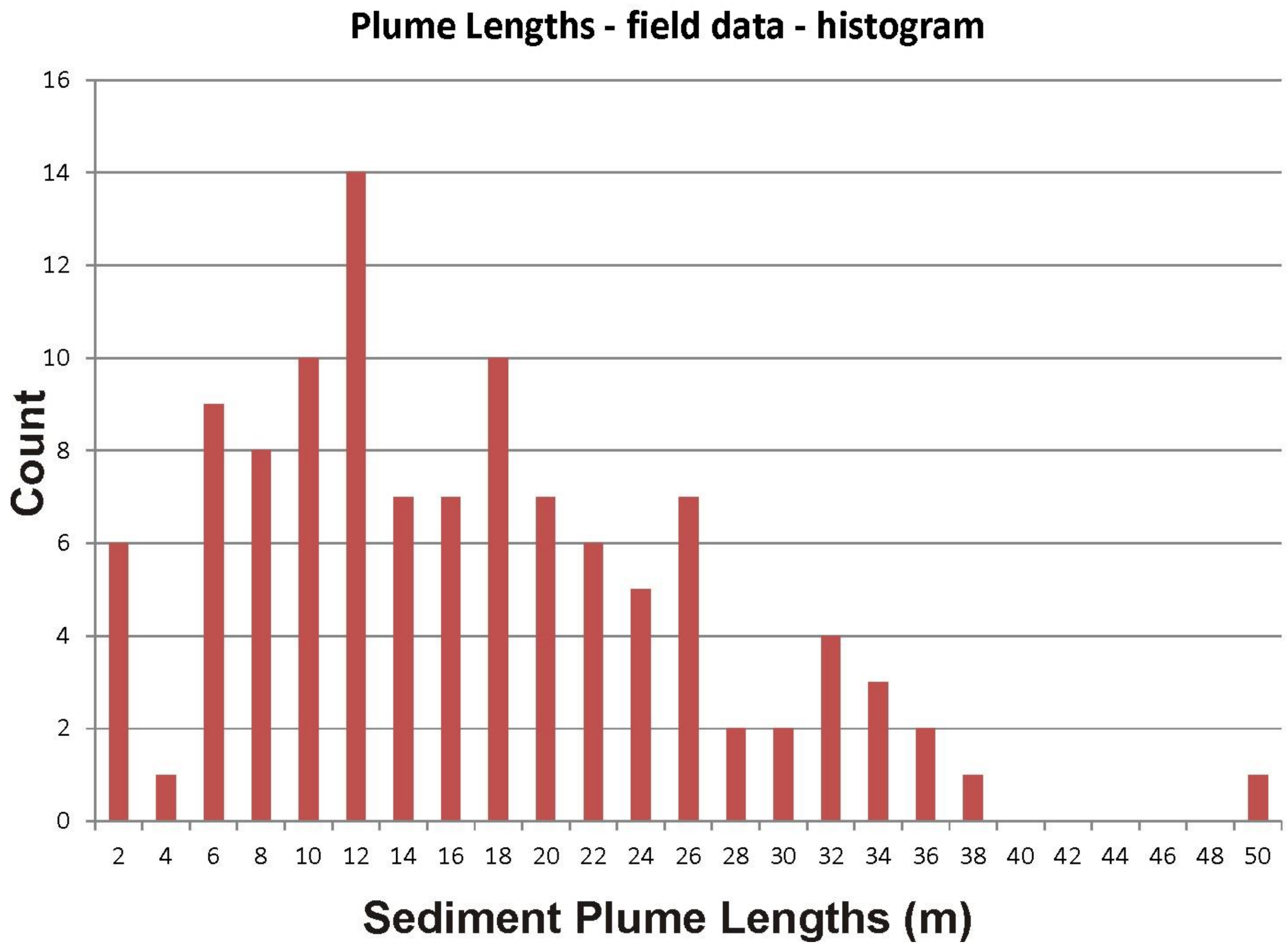
Identifying Unpaved Road Sediment Delivery to Critical Fish Habitats for Strategic Prioritization of Mitigation Actions in Alberta

For Forest Resource Improvement Association of Alberta

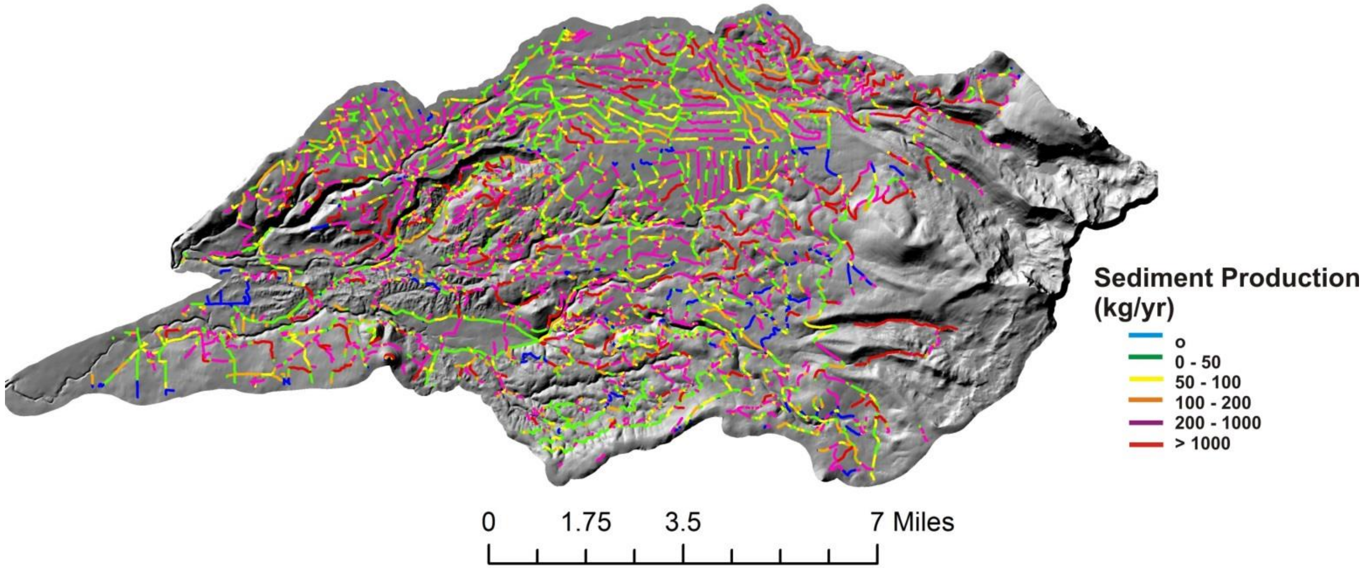
TerrainWorks Inc. and Foothills Research Institute

7-15-2018

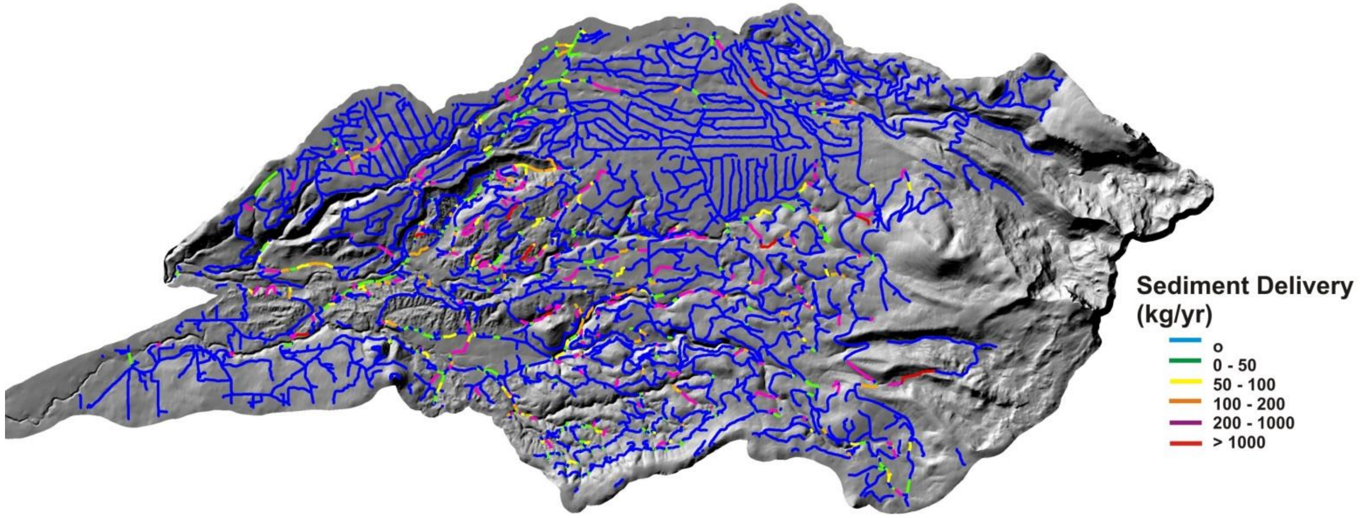
Calibration and Validation


Plume Lengths - field data - histogram
Count
Sediment Plume Lengths (m)
0
2
4
6
8
10
12
14
16
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50

Sediment production versus sediment delivery to streams

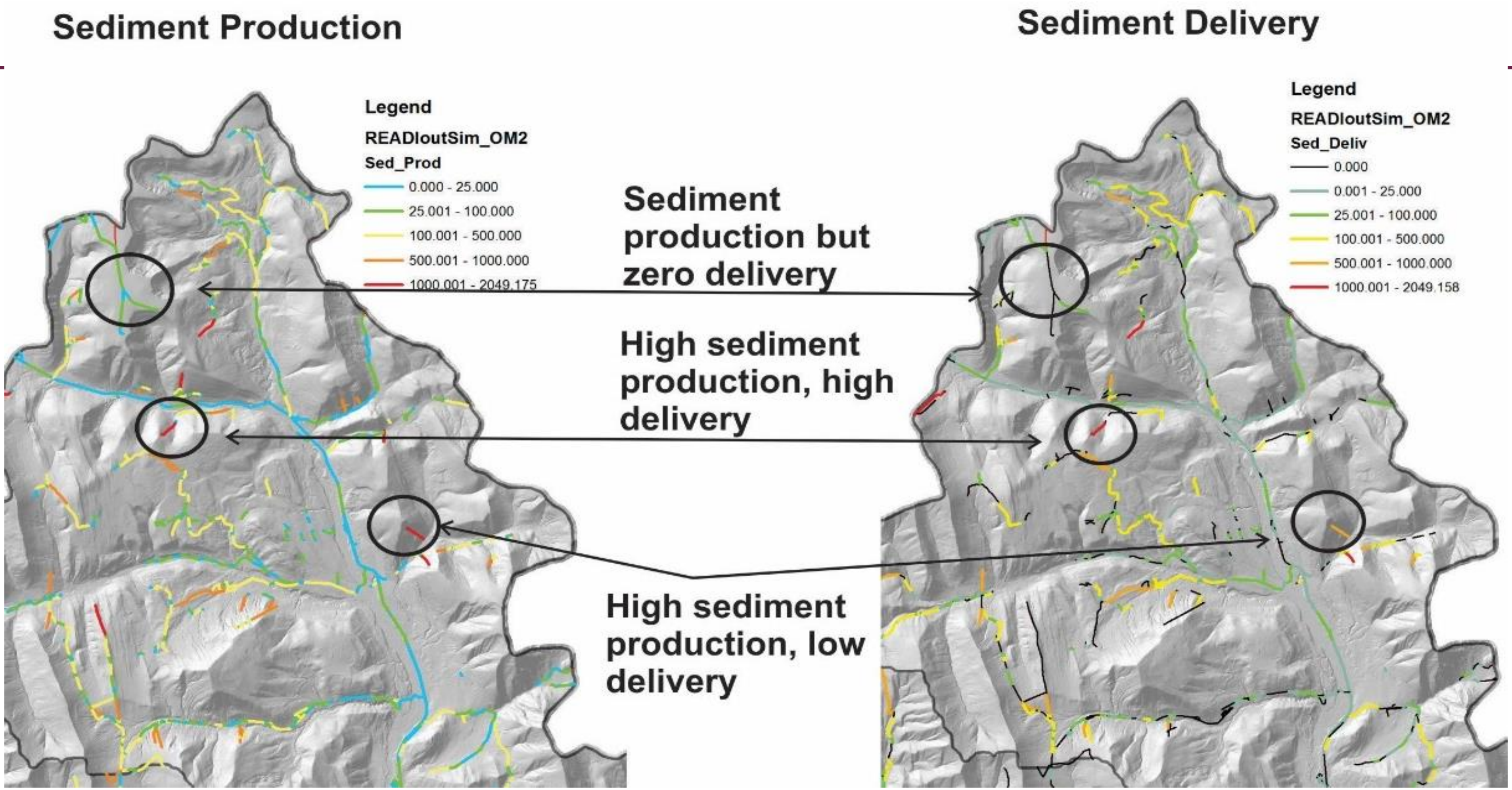


Almost 100% of roads produce sediment



Only a fraction of road segments (10-20%) deliver sediment to streams

Results – Upper Oldman Watershed



Before drain optimization

Perc Deliv: 37.89
Mean Plume: 33.8
Perc Conn: 36.58
Perc Delivered: 37.89 (62.11% not delivered)

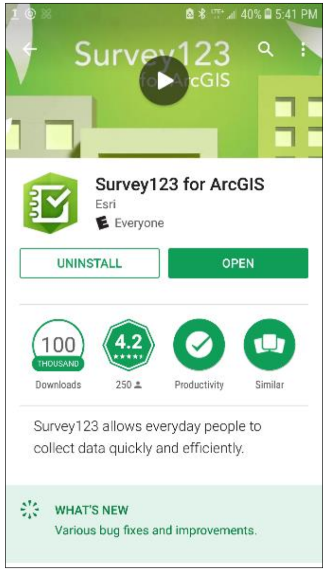
After drain optimization

Perc Deliv: 5.44
Mean Plume: 21.41
Perc Conn: 3.28
Perc Delivered: 5.44 (94.56% not delivered)

Focusing on 4 highest delivering drains sediment delivery potential could be reduced by 70% leaving only 9% of the road network connected to streams.

Watershed Decision Support Tools

- All roads erode, only some have impacts
  - Can identify non-point source pollution
  - Can identify risk at different scales
  - Can prioritize inspections
  - Can identify restoration opportunities w/ greatest benefit
- Cumulative effects tools for watershed values
  - Watershed Integrity and water quality
  - Land-use planning (CE) frameworks
  - Decision support tools (public data)
- Capitalize on technology and innovation
  - Lidar based
  - Digital data collection makes results real-time
  - Gain efficiencies (effort & resources)



Alberta Government

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