Uncertainty Considerations and Prioritization of Recommended Phase 1 Erosion Studies

Presented By

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Background

Uncertainty in Erosion Prediction

Prioritization of Studies

Conclusion

Background

Timeline:

- ***EWG Recommended Phase 1 Erosion Studies (report submitted July 2012)***
    - Study area 1 - Terrain Analysis
    - Study area 2 - Age Dating and Paleoclimate
    - Study area 3 - Recent Erosion and Deposition Processes
    - Study area 4 - Model Refinement, Validation, and Improved Erosion Projections
- ***Stakeholder agency and public feedback received by September 2012***
- ***Independent Scientific Panel (ISP) review received January 2013***

Background *(cont.)*

***Timeline* (cont.):**

- ***Agencies requested that EWG address uncertainty in erosion prediction and prioritization of studies to reduce uncertainty – June 2013***
- ***EWG report on uncertainty and prioritization submitted September 2013***

Background *(cont.)*

The agencies requested additional input from the EWG in the form of two tasks:

- TASK 1: Prepare a report on uncertainty estimates for a broad range of erosion prediction methodologies applied over a range of space scales (hillslope to watershed) and timescales (decadal to multi-millennial scale)

- TASK 2: Conduct an assessment of study recommendations 1, 2, and 3 in the July 2012 report. The analysis should focus on identification and prioritization of studies/study components likely to reduce uncertainties in erosion predictions (as identified in Task 1) regardless of the type(s) of erosion prediction application(s) (e.g. landscape evolution model, hillslope gully model, etc.) or the analysis framework (i.e. probabilistic vs. deterministic) that may be applied at the site in the future.

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Sources of Uncertainty

Erosion working group identified six sources of uncertainty:

1. **Experimental:** uncertainty in measurement
   - Example: error in measuring stream flow
2. **Estimation:** uncertainty in mathematical prediction
   - Example: estimating stream flow velocity with an equation
3. **Temporal:** uncertainty in future conditions
   - Example: uncertainty in future climate

Sources of Uncertainty
(continued)

4. **Theoretical:** uncertainty due to limitations in theory
   - Example: estimating long-term average hillslope erosion with a diffusion equation
5. **Geologic:** uncertainty in interpretation of geologic features
   - Example: uncertainty in dating stream terraces
6. **Cognitive:** uncertainty in documentation / communication
   - Example: uncertainty arising from published descriptions of site stratigraphy

Uncertainty and Sensitivity

Parameters used in erosion models can be characterized in terms of *uncertainty* and *sensitivity:*

- Uncertainty: what is the range of possible or likely values?
  - Example: gravitational acceleration varies slightly across earth but is known to very high precision
  - Example: permeability of natural sediments can vary by orders of magnitude
- Sensitivity: how much does the parameter matter?
  - Example: 10% uncertainty in stream slope leads to about 3% uncertainty in flow depth
  - Example: 10% uncertainty in flow depth translates into >15% uncertainty in sediment transport

Uncertainty in Erosion Prediction

TASK 1: Uncertainty Evaluation Methodology

Rank erosion model parameters and inputs in terms of both sensitivity and (current) uncertainty:

1. LOW:
   - Well known and/or limited range of natural variation — Weak sensitivity
2. MODERATE:
   - Moderate range of possible values — Linear sensitivity
3. HIGH:
   - Values poorly known and/or have wide potential range — Strong sensitivity

Uncertainty and Sensitivity

Gully erosion and landscape evolution model parameters with greatest potential for uncertainty reduction:

- Parameters describing material resistance to erosion and transport
  - Hydraulic detachment threshold and rate coefficient; particle size; bulk density
- Precipitation parameters
  - Frequency, depth, intensity, duration
- Morphologic parameters
  - Headcut height; channel geometry
- Soil hydrologic properties
  - Infiltration capacity

Uncertainty and Sensitivity

Site geologic and geomorphic characteristics with greatest potential for uncertainty reduction:

- Influence of documented postglacial climate events in the area
  - Example: Younger Dryas cold period, c. 12.8-11.5 ka
- Average rates of erosion since the last glacial maximum
  - Example: average rate of lowering on Buttermilk Creek near Frank's Creek confluence
- Overall geologic and geomorphic history of the site
  - Example: when did ice retreat and channel incision begin?

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Prioritization of Studies

Study areas 1 and 2

TASK 2 – Prioritization:

<u>Focus of study areas 1 (Terrain Analysis) and 2 (Age Dating)</u>:

The following three tasks were identified for additional study (ranked in order of relative importance):

1. Relate postglacial climate events to stratigraphy or erosion and deposition, and their discrete history with time;
2. Calculate average rates of erosion since the last glacial maximum; and
3. Construct a geologic and geomorphic history of the WVDP.

Prioritization of Studies

Study areas 3 and 4

TASK 2 – Prioritization *(continued):*

Focus of study area 3 (Recent Erosion and Deposition Processes):

Focus data collection on refining estimates and quantifying uncertainty for parameters related to:

1. Material resistance to erosion and transport;
2. Precipitation
3. Morphology; and
4. Soil hydrologic properties.

Study area 4 (Modeling) would make use of refined geologic, material, and process data. Study area could include sensitivity analysis and uncertainty analysis.

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Conclusion

- ***The EWG has evaluated uncertainty in the context of erosion prediction technology over a range of space scales and time scales. This evaluation allowed the EWG to characterize and rank erosion model parameters in terms of uncertainty and sensitivity***
- ***The EWG revisited the recommended Phase 1 erosion studies and prioritized those activities that have the greatest potential for reducing uncertainty, regardless of the type of erosion prediction application or analysis framework that may be applied at the site in the future***

We Welcome Your Questions . . .

Reserve Slides

Background *(cont.)*

ISP Recommendations:

- The Main Objective of the Studies Should be Clearly Articulated
- Emphasis Should be Placed on Basing the Studies on Sound Science
- The Erosion Recommendations Should Address Uncertainty in More Detail
- The Erosion Studies Should Include Consideration of Natural Analogs
- Collaboration With Other Working Groups is Important
- The Agencies Should Provide Guidance to the EWG on Needed Data Quality Objectives so that the EWG Can Opine on Whether Additional Studies Can Meet the Objectives

Uncertainty in Erosion Prediction *(cont.)*

Uncertainty Index Ranking– Landscape Evolution Model Parameters

Parameter	Current: On-site Data Availability	Current: Uncertainty	Current: Sensitivity	Current: Uncertainty Index	Potential: Uncertainty Reduction	Potential: Revised Uncertainty	Potential: Revised Uncertainty Index	Current-to-Revised Uncertainty Index Ratio
Soil/till detachability	None	3.0	2.0	6.0	Calibration of model to inferred long- to medium-term landscape evolution; field and/or laboratory tests on site materials; estimation of 3D material distribution in subsurface	2.0	4.0	**1.5**
Bedrock detachability	None	3.0	1.5	4.5	Calibration of model to inferred long- to medium-term landscape evolution; estimation of 3D material distribution in subsurface	2.5	3.8	**1.2**
Soil/till detachment threshold	Limited	2.5	3.0	7.5	Calibration of model to inferred long- to medium-term landscape evolution; field and/or laboratory tests on site materials; estimation of 3D material distribution in subsurface	1.5	4.5	**1.7**
Rock detachment threshold	None	3.0	2.0	6.0	Calibration of model to inferred long- to medium-term landscape evolution; estimation of 3D material distribution in subsurface	2.5	5.0	**1.2**
Bed sediment entrainment threshold	Limited measurements on Buttermilk Creek	3.0	3.0	9.0	Field and/or laboratory tests on site materials	1.5	4.5	**2.0**
Fluvial sediment transport coefficient	None	1.5	2.0	3.0		1.5	3.0	**1.0**
Channel width coefficient and exponent	Regional hydraulic geometry data	1.5	2.5	3.8	Field measurements	1.0	2.5	**1.5**
Hydraulic roughness factor	None	1.5	1.0	1.5	Field measurements	1.0	1.0	**1.5**
Soil infiltration capacity	Little to none	2.5	3.0	7.5	Field measurements; calibration to rainfall data and streamflow hydrographs on Buttermilk Creek and tributaries	2.0	6.0	**1.3**
Storm depth, duration, and frequency parameters	Estimates from FEIS analysis	2.0	3.0	6.0	Field measurements and analysis of current data; use modified storm generation model	1.0	3.0	**2.0**
Elevation, slope, and topography	Lidar	1.0	3.0	3.0	Use newly available Lidar	1.0	3.0	**1.0**
Effective angle of repose for till material	Some	1.0	2.5	2.5		1.0	2.5	**1.0**
Hillslope creep coefficient	None	2.0	1.0	2.0		2.0	2.0	**1.0**

Uncertainty in Erosion Prediction *(cont.)*

Uncertainty Index Ranking– Gully Erosion Model Parameters

	Current				Potential			Current-to-
Parameter	On-site			Uncertainty	Uncertainty	Revised	Revised	Revised
	Data Availability	Uncertainty	Sensitivity	Index	Reduction	Uncertainty	Uncertainty Index	Uncertainty Index Ratio
Soil/till detachability	None	3.0	2.0	6.0	Calibration of model to inferred short-term landscape evolution; field and/or laboratory tests on site materials; estimation of 3D material distribution in subsurface	2.0	4.0	**1.5**
Soil/till detachment threshold	Limited	2.5	3.0	7.5	Calibration of model to inferred short-term landscape evolution; field and/or laboratory tests on site materials; estimation of 3D material distribution in subsurface	1.5	4.5	**1.7**
Gully sediment transport coefficient	None	1.5	2.0	3.0		1.5	3.0	**1.0**
Soil particle size and bulk density	Limited	2.5	3.0	7.5	Field and/or laboratory tests on site materials	1.5	4.5	**1.7**
Gully width coefficient and exponent	Regional gully hydraulic geometry data	1.5	2.5	3.8	Field measurements	1.0	2.5	**1.5**
Overland flow hydraulic roughness factor	None	1.5	1.0	1.5	Field measurements	1.0	1.0	**1.5**
Storm depth, duration, and frequency parameters	Estimates from FEIS analysis	2.0	3.0	6.0	Field measurements and analysis of current data; use modified storm generation model	1.0	3.0	**2.0**
Elevation, slope, and topography	Lidar	1.0	3.0	3.0	Use newly available Lidar	1.0	3.0	**1.0**
Soil infiltration capacity	Little to none	2.5	3.0	7.5	Field measurements	2.0	6.0	**1.3**
Headcut height (if applicable)	None	3.0	3.0	9.0	Field measurements	2.0	6.0	**1.5**

Uncertainty in Erosion Prediction *(cont.)*

Uncertainty Index Ranking– Terrain Analysis and Age Dating Parameters

					Uncertainty			Uncertainty
Tasks	**Methods; Tools**	**Data Availability**	**Examples and Potential Outcomes**	**Empirical**	**Cognitive**	**Conceptual**	**Sensitivity**	**Index**
Geomorphic mapping; landform identification	Lidar; aerial photographs; fieldwork; LaFleur geologic maps	Yes; need additional fieldwork	Moraines, terraces, old channels, landslides, alluvial fans, floodplain, modern channel	1	1	1	NA	1
Assign glacial vs postglacial categories	Lidar; aerial photographs; field; LaFleur geologic maps	Yes	Self explanatory as above	1	1	1	NA	1
Assign glacial substages, stadials, interstadials	Literature; OSL; regional correlation	Yes	Literature defined; regional correlations; Heinrich chronology relationships	1	1	2	2	2 to 4
Field confirmation for sampling activities, accessibility	Expert judgement and opinion	Existing reports; update as necessary	Evaluate site accessibility, suitability	1	1	1	NA	1
Rank potential sites for priority sampling	Expert judgement and opinion	Expert judgement and opinion	Liklihood of suitable organic material and OSL site.	1	1	2	2	2 to 4
Sampling phase	Augering; drilling. digital images	Needs discussion	Auger rather than trenching. Greater sample density than previously for selected sites	1	1	2	2	2 to 4
List potential climatic episodes	Literature from Finger Lakes; Great Lakes; northern hemisphere	Yes, especially Seneca Lake studies	See text	1	1	2 or 3	2	2 to 4
Relate postglacial climate events to stratigraphy or erosion/deposition and discrete history	Expert judgement and opinion; tree-ring analysis	Literature studies; especially Seneca Lake studies	Depends upon sample dating results	2	2	3	3	6 to 9
Construct geologic and geomorphic history	Expert judgement and opinion.	Expert judgement and opinion	Depends upon sample dating results	1	1	2	2	2 to 4
Calculate average rates of erosion	Sites to be selected	To be obtained	Depends on sampling and dating results	1	1	2	3	6 to 9

Prioritization of Studies

TASK 2 – Prioritization:

The uncertainty and sensitivity rankings for each parameter evaluated in Task 1 were used to prioritize the parameters with the greatest uncertainty indices and the greatest opportunities for uncertainty reduction through additional studies.

Landscape Evolution Modeling:

The following five parameters were identified for additional study for the LEM (ranked in order of relative importance):

1. Bed sediment entrainment threshold;
2. Soil/till detachment threshold;
3. Storm depth, duration, and frequency parameters;
4. Soil/till detachability; and
5. Soil infiltration capacity.

Prioritization of Studies
(cont.)

TASK 2 – Prioritization (cont.):

Gully Erosion Modeling:

The following six parameters were identified for additional study (ranked in order of relative importance):

1. Soil/till detachment threshold;
2. Soil particle size and bulk density;
3. Headcut height (if applicable);
4. Storm depth, duration, and frequency parameters;
5. Soil/till detachability; and
6. Soil infiltration capacity.