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Title: Freeze-Thaw Effects on Soil and Bank Erosion and Bank Stability

Topic Area: A2.1b Sediment Processes – Cohesive

Objective: Provide knowledge of local- and regional-scale sediment mobilization and erosion that is required to fill the major gaps in science regarding 1) dominant processes in overland and bank erosion where seasonal soil frost forms, and 2) the relationships between soil erodibility, bank-failure susceptibility, soil-moisture redistribution and thaw weakening caused by soil freeze-thaw (FT).

Problem: Previous research has found that 1) soil FT effects are some of the least understood aspects of soil-erosion and overland sediment-transport processes, and 2) soil and bank erosion and bank mass failures induced by soil FT cycling are major processes of sediment mobilization. This project will address these FT-induced processes and will provide knowledge of the regional processes of erosion and bank failure along river, lake and reservoir systems. The data from this project will be used as building blocks for better descriptions of long-term processes being developed in RSM Task A Processes Topic Areas A1 and 3, which require data on bank and shore erosion, reservoir infilling, and shoreline evolution and slumping. The project will fill science gaps for RSM Task B Modeling and Assessment (MA), which requires data to model the seasonal variations in sediment sources and data on bank morphology, erosion rates, and sediment budgets.

Benefits: Knowledge gained from this project will advance Corps capabilities to understand sediment processes and manage sediment resources in cold climates as found in the upper Mississippi, Illinois, Ohio, and Missouri River systems. Results of this project will directly address the following Corps field needs listed in the appendix: 16-Need process-based n-line model, capable of modeling erosion of cohesive bluffs and nearshore; 27-Impact of reservoir operations on streambank erosion; 39-Physical processes related to biostabilization of streambanks (selection and design criteria); 69-Tools to identify defining events for channel morphology; 74-Debris flow (frequency and quantity); 75-Source of sediment; 79-Better spatial definition of hydrologic and sediment processes; and soil conservation, conservation/natural resources; 96-Soil conservation, conservation/natural resources.

The results of this research will support the Navigation, Flood and Storm Damage Reduction, Environmental Protection and Quality, Multi-Purpose, and Regulatory Corps' business programs. Improved water quality and decreased environmental degradation should result from application of techniques to reduce FT effects on soil and bank erosion and stability. Results will supply knowledge on erosion by FT processes to the work units "Watershed Scale TMDL Model," and "Regional Sediment Model."

This work produces new tools and methods for the USACE and nation. It is an integral part of the Regional Sediment Management Research Program, and thus contributes primarily to support of the USACE's navigation, flood/storm damage reduction, and environmental protection and quality missions. It supports all 8 Civil Works strategic goals and 7 of 9 Listening Session objectives identified by HQUSACE as R&D priorities. With companion work units, it employs active technology transfer and insertion.

Work Description: Soil and bank erosion and mass failures are caused by numerous hydraulic and geotechnical processes which interact temporally and spatially in complex ways. These processes supply sediment to rivers, lakes and reservoirs and result in bankline recession and migration. Frost-susceptible soils are composed of cohesive, fine-grained sediment that freeze and thaw from fall through spring. Ground-ice formation and melting associated with FT cycling disrupt the structure and increase the unit weight of soils. This significantly reduces soil-particle cohesion and strength. Particles in a frozen, ice-filled soil are tightly bound and highly resistant to water erosion and soil failures. However, when this soil thaws it has low cohesion and high water content and its strength is often at an annual low making its particles highly erodible and the soil mass highly deformable. Consequently, overland runoff and floods in the spring can often erode significantly more soils than at other times of the year after the soils have drained and regained their strength. Previous studies show that processes related to soil FT usually cause more overland erosion and bankline recession annually than other processes in areas where seasonal frost forms. Erosion models as currently configured use soil erodibility coefficients, which are not adjusted to account for major seasonal variations caused by FT-induced soil moisture and structure changes.

Specific steps to fill this knowledge gap are:
1) Design and complete lab experiments to relate erosion of a frost-susceptible soil to FT weakening, soil moisture, slope and overland flow rate.
2) Select field sites with different soils and hydrology in coordination with the work unit, "Framework for Integrated Solutions".
3) Measure seasonal changes in soil moisture and strength to define FT weakening.
4) Relate these changes to the number of freeze-thaw cycles, the depth of ground frost, and the antecedent soil moisture conditions.
5) Measure sediment lost by water erosion and bank failures during spring thaw.
6) Measure the rate of recovery of soil strength to pre-FT conditions.
7) Develop seasonally adjusted erodibility coefficients from lab and field data.

NRCS and ARS personnel who have addressed erosion processes and bank stabilization will collaborate in site selection and data analysis. Technology transfer will be facilitated through Task E, Technology Transfer via presentations at Corps' workshops and training seminars, technical assistance during visits at Corps' offices, scientific conferences, journal papers, and technical notes and reports. Results will be incorporated into RSM Task B, Modeling and Assessment (MA) for development of sediment budget procedures and advanced erosion/deposition algorithms, Task C, Engineered Solutions (ES) to meet Source Control and Channel and Shore Modification needs, and Task D, Informatics (I) for development of Decision Support tools.

Products and Schedule:

Primary products from this work will be improved knowledge of erosion by FT processes.

Product	Scheduled
1. Paper at Corps workshop or scientific conference – lab results	Q3/02
2. TN: "Overland Erosion Due to Freeze-Thaw Cycling" (to MA)	Q4/02
3. Paper at Corps workshop or scientific conference – field results	Q3/03
4. TN: "Bank Erosion and Freeze-Thaw Cycling" (to MA)	Q4/03
4. TR: "Freeze-Thaw Effects on Sediment Movement in Watersheds" (to MA, ES, I)	Q3/04
JP: "Freeze-Thaw Effects on Sediment Movement in Watersheds"	Q4/04
Input to Engineer Manuals	Q4/04
EM 1110-2-1418 Channel Stability Assessment for Flood Control Projects	
EM 1110-2-1913 Design and Construction of Levees	
EM 1110-2-4000 Sedimentation Investigations of Rivers and Reservoirs	