DESIGN, CONSTRUCTION AND OPERATION OF A STATE-OF-THE-ART EROSION TECHNOLOGY TEST LABORATORY

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ABSTRACT

In recent years, project owners and designers have been clamoring for reliable information on the material and performance characteristics of erosion control materials. Users of these products consider test data as vital information to predict application success for a variety of projects, to evaluate potential materials and installation methods, and to establish project-specific quality requirements. Likewise, quality-conscience manufacturers of erosion control products need this documentation for product research and development; sales and marketing purposes; installation guidelines; and product certification purposes.

Many users and manufacturers have done informal field tests on erosion control products with varying levels of documentation and reliability. Contract testing services are available through a few universities provided fee requirements and scheduling conflicts can be negotiated. This paper details the design and construction of a dedicated, state-of-the-art erosion test laboratory located in Rice Lake, Wisconsin. This outdoor facility is being developed to provide quantitative performance data on erosion control products and materials, under conditions representing both hillslope and channel environments, in a timely and cost-effective manner.

The outdoor facility includes twelve rainfall simulation plots for evaluation of erosion control materials on slope applications. Rainfall intensities of up to 254 mm/hr (10 in/hr) are achieved on the 2.4 m (8 ft) wide by 12.1 m (40 ft) long plots. In addition, the facility includes twelve open-channel flumes for evaluation of erosion control materials in hydraulic applications. Velocities of up to 4.2 m/s (14 ft/s) and corresponding shear stresses of up to 480 N/m^2 (10 lb/ft^2) are achieved at the maximum discharge of 1.7 m^3/s (60 ft^3/s). Detailed information on the design criteria, selection of materials and construction methods is discussed. Unique features of the facility to document key external variables, including meteorological, geotechnical, and agronomical conditions, as well as water quality aspects, are also discussed. Planned testing protocol will be presented as this information becomes available.

BIOGRAPHICAL SKETCHES

Mr. Dwight Cabalka is employed by American Excelsior Company - Earth Science Division, Arlington, Texas and is the National Applications Engineer for the Company. Mr. Cabalka has a Bachelor of Science degree in Civil Engineering from Iowa State University, a Masters degree in Business Administration from the University of Colorado, is a registered professional engineer, and has approximately sixteen years of construction industry experience, including project management work on erosion control product testing. He has also recently been appointed as the Chairman of ASTM Subcommittee D-18.25, Sediment and Erosion Control Technology, which has recently been established to develop material and performance standards for erosion control products and installation methods.

Mr. Paul Clopper is employed by Ayres Associates, Fort Collins, Colorado and is a Senior Water Resources Engineer for the firm. Mr. Clopper has a Bachelor of Science degree in Civil Engineering from the University of California (Davis), a Masters Degree in Civil Engineering (Hydrology and Water Resources) from Colorado State University, is a registered professional engineer, and has approximately seventeen years of consulting experience in water resources. His work experience includes management of a large scale hydraulic research facility for Simons, Li & Associates, development of revetment testing protocol and analytical methodologies for the Federal Highway Administration, preparation of design and product selection criteria for three proprietary concrete block revetment systems, and involvement on numerous erosion control material testing projects and field applications.

INTRODUCTION

Documentation of product performance has become an issue of paramount importance in the erosion and sediment control industry. End-users and designers are more frequently requesting this information to provide the basis for construction project designs, specifications and installations. Performance data is also valuable to manufacturers, so that they can provide realistic expectations to end-users, designers and installers. This information is also central to product research and development; sales and marketing activities; installation guidelines; and product certification. With the development of a more sophisticated sediment and erosion control market, it is imperative that advancements in product performance testing be pursued.

Currently, information on performance is often difficult to secure or is of questionable accuracy. A few universities offer facilities for testing of erosion control materials and methods. However, comprehensive testing programs conducted at these facilities require a considerable amount of capital and often run into the tens of thousands of dollars. In addition to the high cost, university facilities are also typically scheduled many months in advance, making rapid testing of erosion control products difficult. And there are no commercial organizations or test labs available at present to do performance testing of erosion control materials and methods.

Informal field testing has therefore been the primary source of information on product performance. While actual field results amassed over a number of years may provide valuable insight on performance, it is often difficult to translate the results from one site to another. Job site conditions, such as soil, topography, weather and treatments, are often undocumented in field studies, yet can vary dramatically from site to site. And the quality of materials and installation, also typically undocumented, can have a significant effect on the field performance of erosion control solutions.

In order to provide timely and reliable information on the performance of erosion control products and materials, American Excelsior Company (AEC) has sponsored the development of an in-house test facility near its manufacturing plant in Rice Lake, Wisconsin. The decision to construct this facility, known as *The ErosionLab*, was based on four primary factors: (1) the need to document performance of existing AEC products; (2) the desire to examine competitive materials; (3) the need to evaluate different methods of installation, and; (4) the requirement to develop new solutions for erosion control applications.

Although the Company has successfully furnished erosion control products to countless projects over the past thirty years, the need for carefully quantified data on performance in typical applications was determined to be a number-one priority. Since the mid-'80s, many competitive materials have entered the erosion control market; each with their own claims on performance - some realistic and some not. Based on the competitive nature of the erosion control market, the evaluation of competitive materials was determined to be an important goal. Aside from the materials themselves, it was decided that related work, such as soil preparation, anchor patterns, and termination details, should also be evaluated. There is currently very little, if any, data available on these related topics which in all likelihood have a significant effect on performance. And finally, the desire to improve existing solutions and to innovate new solutions for erosion control applications was a major objective.

The ErosionLab will be tasked with determining the capabilities of a wide variety of products and methods to determine performance as related to two basic criteria (1) the ability to control erosion and reduce sediment loss prior to the establishment of vegetation, and (2) the ability to accelerate seed germination and enhance the establishment of vegetation. As discussed later in this paper, generally accepted scientific principles will be applied to the test protocol, including documentation of existing conditions, use of control cases, certification of the materials/methods being applied, documentation of the test itself, and collection of data. The analytical and reporting activities related to these tests will also adhere to generally accepted statistical principles and reporting procedures.

To assure the integrity of this facility's design and its operation, the Company selected an independent engineering consultant, Ayres Associates in Fort Collins, Colorado, to assist in the development of a Feasibility Study, including site selection, preliminary design and budget analysis. This study was concluded in early summer 1996 and has been accepted as the basis for development and construction of *The ErosionLab*.

SITE CHARACTERISTICS

The ErosionLab site comprises a portion of the American Excelsior Company's 46-acre wood storage yard located near their manufacturing facility in western Wisconsin, near the town of Rice Lake. Historically, the site has been used for the storage of approximately 10,000 cords of aspen logs which require a 12- to 18-month drying and curing period.

A picturesque, 5-acre pond, created by sand and gravel borrow operations for the construction of nearby State Highway 53, is located on the site. The pond water surface is maintained at the natural level of the groundwater table and has no discharge outlet. Grassed slopes form a ring 91m wide (300 ft) around the periphery of the pond, with slope gradients ranging from about 6 to 12 percent. Onsite soil is predominantly Chetek sandy loam, a fine- to medium-grained noncohesive soil which exhibits rapid infiltration rates. Forested buffer strips several hundred feet wide separate the property from adjacent lands and from the nearby Red Cedar River. **Figure 1** provides a view looking across the pond showing the wood storage piles in the background.

Figure 1. Pre-construction view of *The ErosionLab* site (November, 1995).

The on-site pond offers a ready source of clear water for conducting both rainfall and channel erosion studies. Other opportunities and constraints for facility development at the site were identified during initial site reconnaissance, survey, and characterization by the American Excelsior - Ayres Associates site development team, as summarized below.

SITE DEVELOPMENT OPPORTUNITIES / ADVANTAGES	**SITE DEVELOPMENT CONSTRAINTS / DISADVANTAGES**
• Ready source of water for test discharges • No discharge to offsite receiving waters • Natural slopes at ideal grades minimize earthwork • Convenient access to consultant's headquarters office • Appropriate zoning for industrial activities • Close proximity to manufacturing facilities • Site owned by American Excelsior Company • Well-buffered site with good access	• Clayey and silty soils must be imported • Testing period restricted by seasonal conditions • Sediment traps required to minimize impact to pond • High infiltration capacity of onsite soils requires lining of water supply channels

FACILITY LAYOUT AND DESIGN

In order to generate hydraulic forces suitable for product testing in an open channel environment, Ayres Associates recommended that a pumping facility capable of discharging up to 1.7 m^3/s (60 ft^3/s or 27,000 gallons per minute) be established. At test durations of up to one hour per run, this flow rate require as much as 5 acre-feet of water for each test.

The large discharge capacity for the channel tests ultimately dictated the overall layout of the facility. Ayres Associates' design team successfully integrated the best elements from two premier research facilities which pioneered full-scale channel lining testing methodology throughout the 1980s: Great Britain's Construction Industry Research and Information Association's research laboratory at Jackhouse Reservoir in England (CIRIA 1987) and the Simons, Li & Associates Overtopping Flume facility in Colorado (Clopper and Chen 1988). The general development concept centered around a water recycle theme which calls for all channel discharges to be pumped from the pond into one of twelve test channels. After coursing down the test channel, the water passes through a main desilting basin where filtration through porous sediment logs occurs before being returned to the pond. This recycle scheme results in a non-consumptive use of the reservoir water, and no use fees or water rights impacts are incurred.

For the rainfall erodibility portion of the facility, much less water is required for the conduct of each test. A maximum rainfall intensity of 254 mm/hr (10 in/hr) results in a required flow rate of about 3.8 l/s (60 gallons per minute), considering test plot area and overspray requirements which ensure uniform rainfall coverage. Considering a test duration of 20 minutes, each test will utilize about 2,600 liters (700 gallons) of water over the plot area. That portion of the water which runs off during a test will be collected, measured, and analyzed for sediment concentration as well as selected chemical parameters (fertilizers and other agricultural chemicals). Individual plots are separated from each other by 3.6 m (12 ft) wide accessways, and run-on control is provided by heavy-duty landscape edging which borders each plot.

Figure 2 provides a plan view of the site showing the locations of the major features of *The ErosionLab* facility.

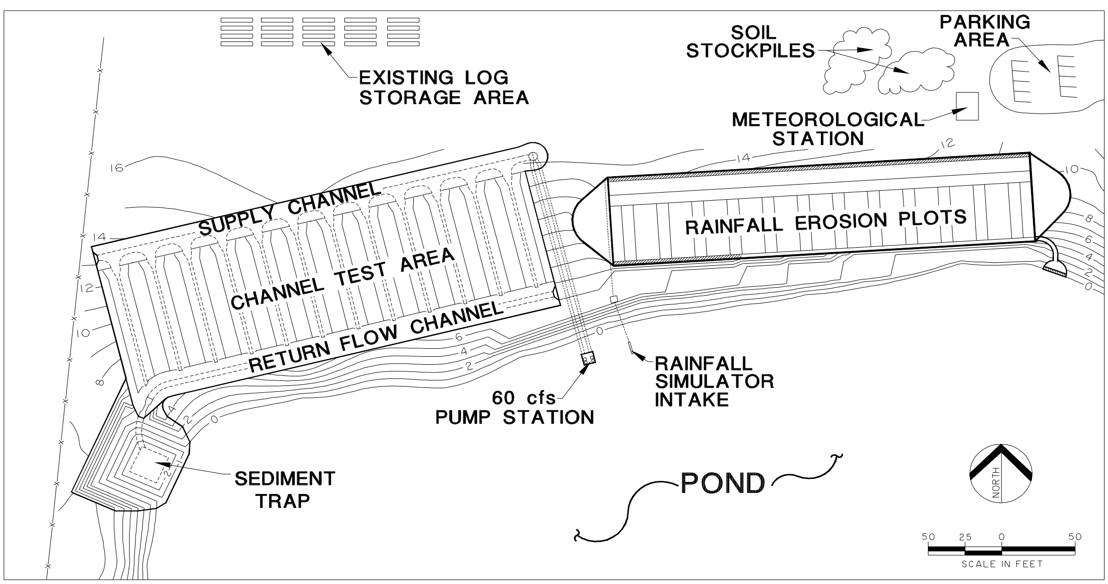

Figure 2. Plan view of *The ErosionLab* facility.

PERMITTING AND CONSTRUCTION

Permitting Requirements

In accordance with State of Wisconsin regulations, *The ErosionLab* was permitted for construction by the Department of Natural Resources (DNR). To assure protection of water resources, including water quality and the aquatic environment, Wisconsin State Law, Chapter #30, "Navigable Waters, Harbors and Navigation," which establishes the permit program for construction projects which qualify under a variety of conditions. The conditions which applied to *The ErosionLab* selected location included: (1) a site located within five hundred feet (500') of a navigable waterway; (2) a site totaling in excess of ten thousand square feet (10,000 sf) of grading work, and (3) placement of any structure upon the bed of any navigable waterbody.

The facility is sited on a man-made pond which was excavated in the early-1970s to provide fill material for a nearby bridge abutment on SH 53. Surface water enters the pond only through overland flow, since no channels (either natural or man-made) provide inflows. In addition, the pond has no outflow through surface channels. However, the facility lies within approximately 75 m (250 ft) of the Red Cedar River which, being a navigable waterway, places permitting requirements on the facility. Since the site covers an area of approximately 5,500 m^2 (60,000 ft^2), it exceeds the threshold for grading permit requirements. Also, the construction of a permanent platform in the pond to support the low head vertical pumps that supply the channel area also require DNR permits.

On August 23rd, 1996, an application for the above referenced permits (Form 3500-53) was filed with the Wisconsin DNR following an on-site meeting and plan review by Mr. Ed Slaminski, District Representative for the DNR. In accordance with the DNR permitting requirements, a public announcement was placed in the Rice Lake Chronograph, the Rice Lake, WI weekly newspaper, and a thirty day comment period followed. No comments were received during this announcement period, which closed on September 27th, 1996, and on October 7th a construction permit was issued by the DNR.

In addition to the State of Wisconsin DNR permitting process, *The ErosionLab* plans were submitted to the US Army Corps of Engineers Central Permits Section for consideration, but after review were determined not to fall within the regulatory jurisdiction of the Corps of Engineers.

Construction Phasing

Construction of the laboratory was split into two phases due to anticipated late fall weather conditions in the upper-Midwest. Phase I involved all site work and grading for both the channel and rainfall erosion areas, and completion of the rainfall erosion test plots, including installation of underground piping. Phase II will involve completion of the channel area, which includes: (1) construction and installation of the pump platforms; (2) installation of the pumps and diesel engines; (3) installation of piping, and (4) construction of water control structures (e.g., pipe outfalls, headgates and head/tail channel linings).

The priority for construction of the rainfall test plots was based on the limited remainder of the Autumn 1996 construction season. The master schedule indicated that this construction would require approximately four weeks to complete while the channel area would require approximately eight weeks. With only approximately three weeks of estimated work time left in the fall construction window, it was decided to focus on construction of the rainfall erodibility test area.

Construction Activities

American Excelsior executed a contract with B&B excavating of Rice Lake, Wisconsin, for site earthwork and construction began on October 14th with the stripping of vegetation and stockpiling of topsoil. Ayres Associates' earthwork computations indicated that material excavated to create the channel area would approximately balance the fill material needed to construct the berm required for the rainfall plots. To meet the design requirements, approximately 1,800 m^3 (2,400 yd^3) of cut and 1,725 m^3 (2,300 yd^3) of fill were estimated, exclusive of "veneer" material required for the test surfaces. Three veneer materials (sand, clay and silty loam) were selected for surface treatment, totaling approximately 2,100 m^3 (2,800 yd^3) split equally. Excavated material from the channel area was placed in the slope berm in 15-cm (6-inch) lifts and compacted using conventional earthmoving equipment. Total earthwork activities accounted for approximately three weeks of construction.

The slope area construction was completed with the trenching and installation of a 20-cm (8-inch) diameter polyvinylchloride (PVC) pipe to convey water from the portable pump up to the top of the berm. A manifold was then constructed using like pipe to distribute water to the top of each of the twelve test plots. PVC risers 7.5-cm (3-inch) in diameter were then installed and capped.

Due to the onset of winter weather conditions, on site construction activities concluded in early November. Fabrication and construction of the sprinkler risers were performed during the winter months in anticipation of testing activities in the spring. Likewise, forming and construction of the precast concrete pump platform was completed during the winter months. Local ordinances restricting vehicle loads in the early spring on county roads made it imperative that the majority of the "heavy work", including earthwork and equipment deliveries, be completed prior to that time. **Figure 3** shows the initiation of construction activities in the fall of 1996.

Figure 3. Excavation of *ErosionLab's* sedimentation basin, October, 1996.

FACILITY OPERATIONS

The facility design and layout was specifically developed to allow flexibility in testing methods and data collection procedures. We expect that a range of slopes, channel geometries, and measurement/analysis techniques will be evaluated at *The ErosionLab* over the course of the next few years. Critical to the success of the program will be the adherence to strict documentation and reporting procedures, to include a thorough description of pre-test versus post-test conditions. This fundamental precept pertains to control runs as well as tests of specific treatments, and to channel tests as well as hillslope rainfall simulations. Conditions to be documented include soil properties, subgrade preparation and geometry, meteorological conditions, product/material properties, application rates for straw or mulch treatments, installation specifics (staple patterns, transverse check slots, etc.) and vegetation types and densities. The following sections describe the initial testing and data collection protocols anticipated.

Channel Tests: In order to test a full range of hydraulic conditions, twin vertical-lift pumps, each capable of delivering 0.83 m^3/s (30 ft^3/s or 13,500 gpm), will be mounted on precast concrete sumps and driven by 6-cylinder, 300 horsepower diesel engines. By varying the speed of the engines, a smooth range of discharges up to a total capacity of 1.7 m^3/s (27,000 gpm) can be achieved.

The trapezoidal cross section of the test channel will have maximum side slopes of 2H:1V, which is representative of typical drainage facilities, including highway ditches, landfill drainageways, and many municipal stormwater management facilities. Longitudinal slopes of up to 10 percent will allow velocities and shear stresses to reach about 4.2 m/s (14 ft/s) and 480 N/m^2 (10 lb/ft^2), respectively, depending on system roughness. The intent of the channel design is to allow investigation of a wide spectrum of channel lining materials ranging from blown-on products and blankets to riprap and concrete block revetments.

Three base soils will be utilized in the testing program: A sandy loam soil derived from onsite borrow areas, a silty clay loam (imported), and a heavy clay (imported). Both the unvegetated condition, as well as vegetated conditions using typical highway seed mix specifications for upper Midwest applications, will be examined. Centerline flow depth and velocity will be measured at five cross sections located at predetermined distances along the channel. Pre-and post-test contour maps of the channel boundary will be developed using total station field measurements downloaded into CAD-compatible earthwork software. This will allow accurate quantification of erosion losses or areas of deposition along the entire test reach, in contrast to the hit-or-miss method of cross-section measurement at predetermined transect locations. Primary performance indicators for the channel tests will include ***quantitative soil loss measurements*** and ***material failure assessments*** (such as stretching, tearing, loss of material, etc.).

Rainfall Erosion Tests: The rainfall simulators are valved to enable uniform intensities of 64, 128, 190, and 254 mm/hr (2.5, 5.0, 7.5, and 10.0 in/hr) to be delivered onto the test plots at drop sizes typical of natural rainfall. Control tests on bare soil will be conducted at each of the prescribed intensities so that indices of ***infiltration*** ("Phi-index" and Green-Ampt "psi"), ***runoff potential*** (Rational coefficient "C" and runoff curve number "CN"), and ***erodibility*** (USLE soil erodibility factor "K") can be developed for bare soil conditions for each of the three soil types.

As with the channel tests, three base soils will be considered: sandy loam, silty clay loam, and heavy clay. Again, both vegetated and unvegetated tests will be conducted. Various manufactured erosion control products, primarily blankets and mulches, as well as generic treatments such as crimped straw, rock mulch, etc. will be tested on a 3H:1V slope. Measurements of runoff rate and sediment yield will be made by collecting the entire runoff output from each test plot at intervals over the entire test duration. Performance parameters of primary interest will include comparison of the infiltration, runoff, and erodibility indices to the corresponding bare soil control. Secondary performance parameters may include vegetation species, cover density, and biomass, and/or concentrations of fertilizer or other agricultural chemicals in runoff.

Operation Manuals

Under contract to American Excelsior Company, Ayres Associates developed two Operations Manuals; one for the hillslope area and one for the channel area. These two documents detail the calibration, instrumentation, installation and data collection requirements for each of these two areas.

To improve the quality and assure the accuracy, the Operations Manuals were reviewed informally by a number of independent, third-party agencies, including several universities, Departments of Transportation and other relevant organizations. Comments and suggestions received as a result of these reviews were incorporated into the Operations Manuals. Although these comments do not reflect a formal endorsement by these organizations, they were certainly useful in the development of the Operations Manuals.

Analysis and Reporting

To assure accurate and reliable assessment of performance, the testing methods, data collection procedures, and analysis techniques for studies performed at *The ErosionLab* will adhere to accepted scientific and statistical principles. Multiple independent tests will be performed for control plots as well as for specific treatments in order to assess the reproducibility of measured results. Comparisons will then be made between control and product to quantify the degree of erosion control provided by the product, the installation technique, or other relevant variable being evaluated.

Testing and data collection will be performed in strict accordance with the Operations Manuals, with any modifications or deviations thoroughly documented. Test conditions and data will be certified by the Facility Manager, National Applications Engineer, and/or Vice President of Manufacturing. In addition, Ayres Associates will provide periodic oversight of selected tests to confirm compliance with the testing protocol. It is also anticipated that from time to time, other third party organizations may oversee or participate in testing activities, including set-up, operation, data collection, and reporting. Prior to publication, all analyses will be performed by an independent registered professional engineer with specific expertise in erosion control, hydraulics, hydrology, and water resources.

SUMMARY

The ErosionLab represents a significant investment in the development of reliable technical information on product performance for the most typical erosion control applications; hillslope erosion due to rainfall, and channel erosion due to concentrated flows. It is anticipated that the data generated will be invaluable in the development of performance-based standards within industry recognized organizations, including the International Erosion Control Association (IECA) and the American Society of Testing and Materials (ASTM).

But as important as detailed standards and specifications are, perhaps the most significant contribution this state-of-the-art facility will offer to the erosion control industry is the ability to establish realistic expectations of performance that can be translated and applied to problem sites throughout the world. By maintaining an end-user perspective, the most economical erosion control solutions can be selected, based on an appropriate level of protection to eliminate both overkill and shortcuts.

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