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END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Not used

1.02 PROJECT DESCRIPTION

.1 The project is to replace an existing ferryway on the Rabbitkettle River in Nahanni National Park. The existing ferryway is used to ferry visitors and staff from the landing area on the Rabbitkettle River across the river to the visitor facilities (trails, etc) on the opposite side of the river. The existing ferryway is past its useful life and is to be removed and a new ferryway installed.

1.03 PROJECT LOCATION

.1 The project is located in Nahanni National Park Reserve on the Rabbitkettle River, in the north-central part of the park at approximately latitude 61.93978 and longitude -127.2193. Access to the site is by air only (helicopter or float plane). Park offices and closest air charter services are located in Fort Simpson, NWT, approximately 300 km to the east of the site. A Parks Canada staff cabin is located approximately 3.5 km away from the project site, at the south end of Rabbitkettle Lake.

1.04 WORK COVERED BY CONTRACT DOCUMENTS

.1 Work covered under the terms of the contract include the following:

.1 Deconstruct and remove the existing ferryway structures and cable from the site and dispose of the materials outside the park reserve at an acceptable recycling or waste disposal site. The boat associated with the existing ferryway is to be salvaged and reused with the new ferryway.

.2 Acquire the necessary materials and equipment and fabricate, transport and install the new ferryway as described in the attached drawings and specifications. Incorporate the existing boat and haul tackle into the new system. The bank protection shown in the accompanying geotechnical report is not included in this scope of work and will be done by others.

.3 Upon completion of installation, remove all waste and excess materials from the site and dispose at an acceptable location outside the National Park Reserve. Reclaim and remediate any disturbed ground that has resulted from the construction of the new ferryway.

1.05 CONTRACT METHOD

.1 Construct Work under Lump Sum price contract.

1.06 WORK SEQUENCE

.1 All the Works are to be completed no later than September 26, 2014

.2 Schedule work progress to allow Departmental Representative unrestricted access to inspect all phases of the Work.

1.07 CONTRACTOR USE **OF PREMISES**

.1 Unrestricted use of site .

.2 Contractor shall limit uses of the premises for Work, for storage, and for access, to allow:
 .1 Owner occupancy

.3 Coordinate use of premises under the direction of the Departmental Representative.

.4 The Contractor and all Subcontractors shall obtain a business license from the Park Administration in the Village of Fort Simpson prior to commencement of the contract.

.5 Remove or alter existing work to prevent injury or damage to portions of existing work which remain.

.6 Repair or replace portions of existing work which have been altered during construction operations to match existing or adjoining work, as directed by Departmental Representative.

.7 At completion of operations condition of existing work: equal to or better than that which existed before new work started.

1.08 OWNER OCCUPANCY

.1 Owner will occupy premises during the entire construction period for execution of normal operations.

.2 Cooperate with the Owner in scheduling operations to minimize conflict and to facilitate Owner usage.

1.09 OWNER FURNISHED MATERIALS

.1 Not Used

1.10 CONSTRUCTION SIGNAGE

.1 No signs or advertisements, other than warning signs, are permitted on site.

.2 Maintain approved signs and notices in good condition for duration of the project, and dispose of off-site on completion of project or earlier if directed by the Departmental Representative.

1.11 EXISTING SERVICES

.1 Not Used

1.12 SETTING OUT OF WORK

.1 Departmental Representative will establish control points and provide:
  .1 Initial set of trail centerline location stakes.
  .2 Detailed cross-section and vertical alignment as part of the drawings.
  .3 Complete set of Construction Drawings

.2 Contractor to
  .1 Set additional control points as necessary
  .2 Set all work stakes necessary to complete the work.
  .3 Not damage geodetic benchmarks unless authorized by Departmental Representative

.3 All survey work required by the contractor to layout, monitor, and provide measurements for quantities for payment is considered incidental to the completion of the Works and will not be considered for separate payment.

1.13 DOCUMENTS REQUIRED

.1 Maintain at job site, one copy each document as follows:
  .1 Contract Drawings.
  .2 Specifications.
  .3 Addenda.
  .4 Reviewed Shop Drawings.
  .5 List of Outstanding Shop Drawings.
  .6 Change Orders.
  .7 Other Modifications to Contract.
  .8 Field Test Reports.
  .9 Copy of Approved Work Schedule.
  .10 Health and Safety Plan and Other Safety Related Documents.
  .11 Other documents as specified.

2 PRODUCTS

2.01 NOT USED

.1 Not used.

3 EXECUTION

3.01 NOT USED

.1 Not used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Section 01 35 31 Submittal Procedures

.2 Section 01 35 43 Environmental Procedures

1.02 REFERENCES

.1 Canada Labour Code, Part 2, Canada Occupational Safety and Health Regulations

.2 Northwest Territories and Nunavut
  .1 Safety Act, R.S.N.W.T. - Updated [2012].

.3 Health Canada/Workplace Hazardous Materials Information System (WHMIS) Material Safety Data Sheets (MSDS)

1.03 ACTION AND INFORMATIONAL SUBMITTALS

.1 Submit in accordance with Section 01 33 00 - Submittal Procedures.

.2 Submit site-specific Health and Safety Plan: Within 7 days after date of Notice to Proceed and prior to commencement of Work. Health and Safety Plan must include:
  .1 Results of site specific safety hazard assessment.
  .2 Results of safety and health risk or hazard analysis for site tasks and operation found in work plan.
  .3 Contractor's Safety Policy.
  .4 Definitions of responsibilities for project safety/organization chart for project.
  .5 General safety rules for project.
  .6 Job specific safe work procedures.
  .7 Inspection policy and procedures.
  .8 Incident reporting and investigation policy and procedures.
  .9 Occupational Health and Safety meetings.
  .10 Occupational Health and Safety communication and record keeping procedures.
  .

.3 Submit 2 copies of Contractor's authorized representative's work site health and safety inspection reports to Departmental Representative weekly.

.4 Submit copies of reports or directions issued by Federal, Provincial and Territorial health and safety inspectors.

.5 Submit copies of incident and accident reports.

.6 Submit WHMIS MSDS - Material Safety Data Sheets

.7 Departmental Representative will review Contractor's site-specific Health and Safety Plan and provide comments to Contractor within 7 days after receipt of plan. Revise plan as appropriate and resubmit plan to Departmental Representative within 3 days after receipt of comments from Departmental Representative.

.8 Departmental Representative review of Contractor's final Health and Safety plan should not be construed as approval and does not reduce the Contractor's overall responsibility for construction Health and Safety.

.9 Medical Surveillance: where prescribed by legislation, regulation or safety program, submit certification of medical surveillance for site personnel prior to commencement of Work, and submit additional certifications for any new site personnel to [Departmental Representative] [DCC Representative] [Consultant].

.10 On-site Contingency and Emergency Response Plan: address standard operating procedures to be implemented during emergency situations.

1.04 FILING OF NOTICE

.1 File Notice of Project with Territorial authorities prior to beginning of Work.

1.05 SAFETY ASSESSMENT

.1 Perform site specific safety hazard assessment related to project.

1.06 MEETINGS

.1 Schedule and administer Health and Safety meeting with Departmental Representative prior to commencement of Work.

1.07 REGULATORY REQUIREMENTS

.1 Do Work in accordance with National Parks Act.

1.08 PROJECT/SITE CONDITIONS

.1 Work at site will involve contact with Territorial Occupational Health and Safety

1.09 GENERAL REQUIREMENTS

.1 Develop written site-specific Health and Safety Plan based on hazard assessment prior to beginning site Work and continue to implement, maintain, and enforce plan until final demobilization from site. Health and Safety Plan must address project specifications.

.2 Departmental Representative may respond in writing, where deficiencies or concerns are noted and may request re-submission with correction of deficiencies or concerns.

1.10 RESPONSIBILITY

.1 Be responsible for health and safety of persons on site, safety of property on site and for protection of persons adjacent to site and environment to extent that they may be affected by conduct of Work.

.2 Comply with and enforce compliance by employees with safety requirements of Contract Documents, applicable federal, provincial, territorial and local statutes, regulations, and ordinances, and with site-specific Health and Safety Plan.

1.11 COMPLIANCE REQUIREMENTS

.1 Comply with Safety Act, General Safety Regulations, R.R.N.W.T.

.2 Comply with Canada Labour Code, Canada Occupational Safety and Health Regulations.

1.12 UNFORSEEN HAZARDS

.1 When unforeseen or peculiar safety-related factor, hazard, or condition occur during performance of Work, follow procedures in place for Employee's Right to Refuse Work in accordance with Acts and Regulations of Territory having jurisdiction and advise Departmental Representative verbally and in writing.

1.13 HEALTH AND SAFETY CO-ORDINATOR

.1 Employ and assign to Work, competent and authorized representative as Health and Safety Co-ordinator. Health and Safety Co-ordinator must:
  - .1 Have site-related working experience specific to activities associated with river crossing infrastructure construction.
  - .2 Have working knowledge of occupational safety and health regulations.
  - .3 Be responsible for completing Contractor's Health and Safety Training Sessions and ensuring that personnel not successfully completing required training are not permitted to enter site to perform Work.
  - .4 Be responsible for implementing, enforcing daily and monitoring site-specific Contractor's Health and Safety Plan.
  - .5 Be on site during execution of Work [and report directly to and be under direction of [Registered Occupational Hygienist] [Certified Industrial Hygienist] [and] [or] site supervisor].

1.14 POSTING OF DOCUMENTS

.1 Ensure applicable items, articles, notices and orders are posted in conspicuous location on site in accordance with Acts and Regulations of Territory having jurisdiction, and in consultation with Departmental Representative.

1.15 CORRECTION OF NON-COMPLIANCE

.1 Immediately address health and safety non-compliance issues identified by authority having jurisdiction or by Departmental Representative.

.2 Provide Departmental Representative with written report of action taken to correct non-compliance of health and safety issues identified.

.3 Departmental Representative may stop Work if non-compliance of health and safety regulations is not corrected.

1.16 BLASTING

.1 Blasting or other use of explosives is not permitted without prior receipt of written instruction by Departmental Representative.

.2 Do blasting operations in accordance with Section 31 23 16.26 - Rock Removal.

1.17 POWDER ACTUATED DEVICES

.1 Use powder actuated devices only after receipt of written permission from Departmental Representative.

1.18 WORK STOPPAGE

.1 Give precedence to safety and health of public and site personnel and protection of environment over cost and schedule considerations for Work.

2 PRODUCTS

2.01 NOT USED

.1 Not used.

3 EXECUTION

3.01 NOT USED

.1 Not used.

END OF SECTION

1 GENERAL

1.01 RELATED SECTIONS

.1 Section 01 35 30 - Health and Safety Requirements

.2 . Section 03 35 33 - Environmental Procedures

1.02 MEASUREMENT PROCEDURES

.1 This work shall be incidental to the Contract and will not be measured for payment.

1.03 ADMINISTRATIVE

.1 Submit to Departmental Representative submittals listed for review. Submit promptly and in orderly sequence to not cause delay in Work. Failure to submit in ample time is not considered sufficient reason for extension of Contract Time and no claim for extension by reason of such default will be allowed.

.2 Do not proceed with Work affected by submittal until review is complete.

.3 Present shop drawings, product data, samples and mock-ups in SI Metric units.

.4 Where items or information is not produced in SI Metric units converted values are acceptable.

.5 Review submittals prior to submission to Departmental Representative. This review represents that necessary requirements have been determined and verified, or will be, and that each submittal has been checked and co-ordinated with requirements of Work and Contract Documents. Submittals not stamped, signed, dated and identified as to specific project will be returned without being examined and considered rejected.

.6 Notify Departmental Representative in writing at time of submission, identifying deviations from requirements of Contract Documents stating reasons for deviations.

.7 Verify field measurements and affected adjacent Work are co-ordinated.

.8 Contractor's responsibility for errors and omissions in submission is not relieved by Departmental Representative's review of submittals.

.9 Contractor's responsibility for deviations in submission from requirements of Contract Documents is not relieved by Departmental Representative review.

.10 Keep one reviewed copy of each submission on site.

1.04 SHOP DRAWINGS AND PRODUCT DATA

.1 The term "shop drawings" means drawings, diagrams, illustrations, schedules, performance charts, brochures and other data which are to be provided by Contractor to illustrate details of a portion of Work.

.2 Submit drawings stamped and signed by professional engineer registered or licensed in the Province of Alberta.

.3 Indicate materials, methods of construction and attachment or anchorage, erection diagrams, connections, explanatory notes and other information necessary for completion of Work. Where articles or equipment attach or connect to other articles or equipment, indicate that such items have been co-ordinated, regardless of Section under which adjacent items will be supplied and installed. Indicate cross references to design drawings and specifications.

.4 Allow 14 days for Departmental Representative's review of each submission.

.5 Adjustments made on shop drawings by Departmental Representative are not intended to change Contract Price. If adjustments affect value of Work, state such in writing to Departmental Representative prior to proceeding with Work.

.6 Make changes in shop drawings as Departmental Representative may require, consistent with Contract Documents. When resubmitting, notify Departmental Representative in writing of revisions other than those requested.

.7 Accompany submissions with transmittal letter, containing:
   - .1 Date.
   - .2 Project title and number.
   - .3 Contractor's name and address.
   - .4 Identification and quantity of each shop drawing, product data and sample.
   - .5 Other pertinent data.

.8 Submissions include:
   - .1 Date and revision dates.
   - .2 Project title and number.
   - .3 Name and address of:
     - .1 Subcontractor.
     - .2 Supplier.
     - .3 Manufacturer.
   - .4 Contractor's stamp, signed by Contractor's authorized representative certifying approval of submissions, verification of field measurements and compliance with Contract Documents.
   - .5 Details of appropriate portions of Work as applicable:
     - .1 Fabrication.
     - .2 Layout, showing dimensions, including identified field dimensions, and clearances.
     - .3 Setting or erection details.
     - .4 Capacities.
     - .5 Performance characteristics.
     - .6 Standards.
     - .7 Relationship to adjacent work.

.9 After Departmental Representative's review, distribute copies.

.10 Submit four (4) prints and one (1)electronic copy of shop drawings for each requirement requested in specification Sections and as Departmental Representative may reasonably request.

.11 Submit four (4) copies of product data sheets or brochures for requirements requested in specification Sections and as requested by Departmental Representative where shop drawings will not be prepared due to standardized manufacture of product.

.12 Delete information not applicable to project.

.13 Supplement standard information to provide details applicable to project.

.14 If upon review by Departmental Representative no errors or omissions are discovered or if only minor corrections are made, copies will be returned and fabrication and installation of Work may proceed. If shop drawings are rejected, noted copy will be returned and resubmission of corrected shop drawings, through same procedure indicated above, must be performed before fabrication and installation of Work may proceed.

.15 The review of shop drawings by the Departmental Representative is for sole purpose of ascertaining conformance with general concept.
  .1 This review shall not mean that Departmental Representative approves detail design inherent in shop drawings, responsibility for which shall remain with Contractor submitting same, and such review shall not relieve Contractor of responsibility for errors or omissions in shop drawings or of responsibility for meeting requirements of construction and Contract Documents.
  .2 Without restricting generality of foregoing, Contractor is responsible for dimensions to be confirmed and correlated at job site, for information that pertains solely to fabrication processes or to techniques of construction and installation and for co-ordination of Work of sub-trades.

1.05 SAMPLES

.1 Not Used.

1.06 MOCK-UPS

.1 Not Used.

1.07 CERTIFICATES AND TRANSCRIPTS

.1 Immediately after award of Contract, submit Workers' Compensation Board status.

.2 Submit transcription of insurance immediately after award of Contract.

1.08 REQUIRED CONTRACTOR SUBMITTALS

.1 This Clause identifies the plans, programs, and documentation required prior to mobilization on site and during the construction phase.

.2 **Pre-Mobilization Submittals**

.1 Submit the following plans and programs to the Departmental Representative for review a minimum of twenty (20) days prior to mobilization to the project site. The Contractor shall not begin any site work until the Departmental Representative has authorized acceptance of the submittals in writing.

.2 The Contractor shall not construe the Departmental Representative's authorization of submittals to imply approval of any particular method or sequence for conducting the Work, or for addressing health and safety concerns. Authorization of the programs shall not relieve the Contractor from the responsibility to conduct the Work in strict accordance with the requirements of Federal or Provincial regulations, this specification, or to adequately protect the health and safety of all workers involved in the project and any members of the public who may be affected by the project. The Contractor shall remain solely responsible for the adequacy and completeness of the programs and work practices, and adherence to them.

  .1 Project schedule, detailing the schedule of the workdays required from the Contractor, subcontractors, supplier and consultants to complete each activity of the project location in order to meet stages specified in Section 01 11 00. In addition for each activity, critical elements that could impact on the schedule to be identified. Submission shall include both a paper copy of the schedule and an electronic copy in Microsoft Projects format.

  .2 List of subcontractors, suppliers, and consultants, their role and their key personnel, including names and positions, addresses, telephone and cellular telephone numbers.

  .3 Contractor Chain of Command, listing key Contractor personnel, including for each name, position, qualification, experience, telephone, and cellular telephone numbers. The list shall include names and telephone/cellular numbers for contact persons who are available on a 24-hour basis in the event of emergencies.

  .4 Work Plan, describing in detail for each activity by work area the contractor’s intended methods of construction, and materials, equipment, and manpower he will use to meet stages specified in Section 01 11 00. The Work Plan has to be linked to the Project Schedule.

  .5 Quality Control Plan in accordance with Section 01 45 00 - Quality Control.

  .6 Environmental Protection Plan (EPP) Which shall meet the requirements of Section 01 35 33 - Environmental Procedures.

  .7 Site Access. It shall include but not be limited to plans and procedures for accessing and transporting workers, equipment, and materials to the work site.

  .8 Survey Plan describing the Contractor’s intended methods of surveying during this project.

  .9 Contractor shall develop an "Emergency Procedures Protocol" in consultation with Parks Canada. Parks Canada will supply the Contractor with a template with contact names and numbers to be used for this purpose.

  .10 Health and Safety Plan - The Contractor shall submit a site specific Health and Safety Plan acceptable to the Departmental Representative. The Contractor shall complete and maintain the

Health and Safety Plan during the Work.

.11 Health and Safety Plan must include:
  .1 Contractor's safety policy
  .2 Identification of applicable compliance obligations.
  .3 Definition of responsibilities for project safety/organization chart for project
  .4 Site specific hazard assessment
  .5 General safety rules for project
  .6 Job specific work procedures.
  .7 Inspection policy and procedures.
  .8 Incident reporting and investigation policy and procedures.
  .9 Occupational Health and Safety meetings.
  .10 Occupational Health and Safety communications and record keeping procedures.
  .11 Results of safety and health risk or hazard analysis for site tasks and operation.

.12 Submit copies of Material Safety Data Sheets (MSDS)

.13 Medical Surveillance: where prescribed by legislation, regulation or safety program, submit certification of medical surveillance for site personnel prior to commencement of Work, and submit additional certifications for any new site personnel to Departmental Representative.

.14 On-site Contingency and Emergency Response Plan: address standard operating procedures to be implemented during emergency situations.

.3 The Contractor shall not begin any site Work until the Departmental Representative has authorized acceptance of the submittals in writing.

.3 **Construction Phase Submittals.**
  .1 Monthly Progress Reports in accordance with Section 01 32 18.
  .2 Weekly Progress Reports that outline the detailed Work (Contractor, subcontractors, suppliers, consultants) completed to date as well as the anticipated Work to be performed the following week on a day-to-day basis. Work to be linked to activities by area or location identified in project schedule and to provide information on materials, equipment and manpower. Also, alternate Work to be identified if work or a portion of, proposed cannot be done due to weather, equipment breakdown, delays in delivery, etc.
  .3 Quality Control Inspection Reports - The Contractor shall maintain a daily inspection report that itemizes the results of all Quality Control inspections conducted by the Contractor. The reports shall be made available for review by the Departmental Representative upon request. A summary of all Quality Control Inspections conducted to date shall be submitted by the Contractor with each request for payment.
  .4 Shop Drawings and Mix Designs - The Contractor shall submit all shop drawings and mix designs required to fabricate and/or conduct the work a minimum 30 days prior to fabrication/production.
  .5 Submit four (4) copies of Contractor's authorized representative's work site health and safety inspection reports to the Departmental Representative and authority having jurisdiction, weekly.
  .6 Submit copies of reports or directions issued by Federal or Provincial

health and safety inspections.

.7 Submit copies of incident and accident reports.

.4 **Project Completion Submittals**

.1 Record Drawings - The Contractor shall submit copies of all Contractor's Drawings revised as necessary to record all as-builts to the Work and the Contractor shall submit a set of Contract Drawings clearly marked as record as-built changes to the Work. The drawings are to be submitted in electronic AutoCad (.dwg) format.

.2 Quality Control Records - The Contractor shall submit a bound and itemized set of project quality control records.

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 NOT USED

.1 Not Used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Not used.

1.02 PRECEDENCE

.1 For Federal Government projects, Division 1 Sections take precedence over technical specification sections in other Divisions of this Project Manual.

1.03 MEASUREMENTS PROCEDURES

.1 Preparation and implementation of an Environmental Protection Plan (EPP) in accordance with this Section 01 35 43 - Environmental Procedures will not be measured separately for payment will be considered incidental to the work.

1.04 NATIONAL PARK REGULATIONS

.1 The Contractor shall ensure all work is performed in accordance with the ordinances, laws, rules and regulations set out in the Canada National Parks Act and Regulations.

.2 The Contractor and any sub-contractors shall obtain a business license from the Parks Canada Administration Office in Fort Simpson, prior to commencement of the contract.

1.05 MACKENZIE VALLEY RESOURCE MANAGEMENT ACT

.1 Execution of the work is subject to the provisions within the Mackenzie Valley Resource Management Act (MVRMA) and subsequent amendments. The Rabbitkettle River Ferry Project has been subject to a Preliminary Screening - " Rabbitkettle Ferry replacement and erosion control of Rabbitkettle River bank at north ferry site ", pursuant to the expectations of the MVRMA. Environmental Protection Plans are the next step to achieve the desired end results of minimal adverse environmental effect as the project is constructed.

.2 Failure to comply with or observe environmental protection measures as identified in these specifications may result in the work being suspended pending rectification of the problems.

1.06 ACTION AND INFORMATIONAL SUBMITTALS

.1 Submit in accordance with Section 01 33 00 - Submittal Procedures.

.2 Before commencing construction activities or delivery of materials to site, submit Environmental Protection Plan for review and approval by Departmental Representative.

.3 Environmental Protection Plan must include comprehensive overview of known or potential environmental issues to be addressed during construction.

.4 Address topics at level of detail commensurate with environmental issue and required construction tasks.

.5 Include in Environmental Protection Plan:
- .1 Names of persons responsible for ensuring adherence to Environmental Protection Plan.
- .2 Descriptions of environmental protection personnel training program.
- .3 Erosion and sediment control plan identifying type and location of erosion and sediment controls to be provided including monitoring and reporting requirements to assure that control measures are in compliance with erosion and sediment control plan.
- .4 Spill Control Plan to include procedures, instructions, and reports to be used in event of unforeseen spill of regulated substance.
- .5 Non-Hazardous solid waste disposal plan identifying methods and locations for solid waste disposal including clearing debris.
- .6 Air pollution control plan detailing provisions to assure that dust, debris, materials, and trash, are contained on project site.
- .7 Contaminant Prevention Plan identifying potentially hazardous substances to be used on job site; intended actions to prevent introduction of such materials into air, water, or ground; and detailing provisions for compliance with Federal, Territorial, and Municipal laws and regulations for storage and handling of these materials.
- .8 Waste Water Management Plan identifying methods and procedures for management.
- .9 Historical, archaeological, cultural resources biological resources and wetlands plan that defines procedures for identifying and protecting historical, archaeological, cultural resources, biological resources and wetlands.

1.07 START-UP AND ENVIRONMENTAL BRIEFING

.1 All staff employed at the construction site will be subject to a briefing regarding their individual and collective responsibilities to ensure avoidable adverse environmental impact does not arise from their activities and personal choices. Employees must attend this briefing before beginning their work at the site. It is recognized new employees may join the Contractor's workforce after the initial round of "environmental briefing". In that case and as required, subsequent "environmental briefings" can be presented as numbers warrant, by arrangement with the Environmental Surveillance Officer (ESO) through the Departmental Representative. Also, some sub-trades may be present at the site for a short time, to perform once-only duties. In these cases, the "environmental briefing" will be replaced by the Contractor explaining the environmental sensitivity at the work location to the sub-trade worker(s), and reviewing highlights of personal conduct expected, with reference to a one-page briefing summary to be provided to the Contractor by the ESO. A copy of this summary will be provided to each sub-trade worker joining the workforce at the site.

.2 Parks Canada may have an ESO or Departmental Representative attending the site to monitor the construction activity for conformance with the EPP. The ESO or alternate designated Parks Canada staff member will present the "environmental briefing". The ESO's main duties are to monitor the progress of the construction on an on-going basis to ensure compliance with environmental protection measures, and to provide guidance through the Departmental Representative, in the event of unanticipated environmental problems. Although the ESO has authority to enforce National Parks Act violations, direction to the Contractor will be the duty of the Departmental Representative.

1.08 CONSTRUCTION SITE ACCESS

.1 Access to the construction site will be by float plane to Gahnîhthah Mîe (Rabbitkettle Lake) followed by 3.5km hiking trail from the lake. Points of access in addition to the existing trail to the ferry construction site will not be required. Materials will be heli-slung to the site from the lake. The Contractor shall review construction access requirements with the Departmental Representative. In consultation with the Departmental Representative, the Contractor shall formulate an agreement for worker transportation to and from the work site.

.2 The Contractor shall ensure that the environment beyond the work limits is not negatively impacted or damaged by construction activities and shall instruct workers that the "footprint" of the project is kept within defined boundaries.

1.09 SITE MANAGEMENT

.1 The Contractor is to prepare an EPP which details how the work limits shall be marked and what procedures will be employed to ensure trespass outside these limits does not occur, to the satisfaction of the Departmental Representative and the ESO.

.2 The Contractor shall control blowing dust and debris generated from the construction site by means such as covering or wetting down materials and rubbish. The work site will be maintained in a clean and tidy condition, free from the accumulation of waste materials, debris and other litter.

.3 Pets shall not be brought to or maintained at the construction site.

.4 Work will be conducted during the period of 8:00– 18:00 to avoid excessive noise disturbance to wildlife and the visiting public.

.5 Leave no trace principles will be followed.

1.10 FIRES, FIRE PREVENTION AND CONTROL

.1 Fires and burning of rubbish on site are not permitted.

.2 Care shall be taken while smoking on the construction site to ensure that the accidental ignition of any flammable material is prevented.

.3 In case of fire, the Contractor or worker shall take immediate action to extinguish the fire provided it is safe to do so. The ESO and the Departmental representative shall be notified of any fire immediately. If not available, the Duty Officer shall be contacted at (867) 695 3732.

1.11 EROSION CONTROL

.1 Develop and submit Erosion and Sediment Control Plan (ESC) identifying type and location of erosion and sediment controls provided. Plan to include monitoring and reporting requirements to assure that control measures are in compliance with erosion and sediment control plan and the EPP.

.2 The regular monitoring and maintenance of all erosion control measures shall be the responsibility of the Contractor. If the design of the control measures is not functioning effectively they are to be repaired. The Departmental Representative and ESO also will monitor erosion control and performance.

.3 Control disposal or runoff of water containing suspended materials or other harmful substances in accordance with local authority requirements.

.4 Backfill material will be stored and contained in an area already disturbed and will be covered to prevent erosion.

1.12 EQUIPMENT MAINTENANCE, FUELLING AND OPERATION

.1 The Contractor shall ensure that all fluid leaks, soil and any debris attached to the construction equipment to be used on the project site shall be removed (e.g. power washing) outside Nahanni National Park Reserve before delivery to the work site.

.2 Equipment fuelling sites will be identified by the Contractor and approved by the Departmental Representative and the ESO. Fuelling sites will be located behind the work site, not between the work site and the Rabbitkettle River. Refueling will be done carefully to avoid spillage. Machinery will not be operated between the construction site and the Rabbitkettle River.

.3 Oil changes, lubricant changes, greasing and machinery repairs shall be performed at locations approved by the ESO or the Departmental Representative. Waste lubrication products (e.g. used containers, used oil, etc.) shall be secured in spill-proof containers and properly recycled or disposed at an approved facility. No waste petroleum, lubricant products or related materials are to be discarded, buried or disposed of anywhere within Nahanni National Park Reserve.

.4 The Contractor shall ensure that all equipment is inspected daily for fluid/fuel leaks and maintained in good working order.

.5 Fuel containers and lubricant products shall be stored only in secure locations specified by the Departmental Representative. Fuel containers or other potentially deleterious substance containers shall be secured to ensure they are tamperproof.

.6 Should water pumps be required during excavation, outlet pipes will be directed into the vegetation on shore, pointed away from the Rabbitkettle River.

1.13 OPERATION OF EQUIPMENT

.1 Machinery will be operated on land only.

.2 Equipment movements shall be restricted to the "footprint" of the construction area. The work limits shall be identified by stake and ribbon or other methods approved by the Departmental Representative. Unless authorized by the Departmental Representative, activities beyond the work limits are not permitted. No machinery will enter, work in or cross over rivers or other water bodies, nor damage aquatic and riparian habitat or plant communities. Some construction shall require working close to watercourses or water bodies. In these instances, the Contractor is to describe measures to be employed to ensure fugitive materials (e.g. rocks, soil, branches) and especially deleterious substances (e.g. chemicals) do not enter any watercourses, to the satisfaction of the Departmental Representative and ESO. Work near the river will be conducted such that materials such as gasoline do not enter the river.

.3 The Contractor shall instruct workers to prevent pushing, placement, leveling, storage or stockpiling of any materials in the trees bordering the right of way or into watercourses or water bodies.

.4 When, in the opinion of Parks Canada, negligence on the part of the Contractor results in damage or destruction of vegetation, or other environmental or aesthetic features beyond the designated work area, the Contractor shall be responsible, at his or her expense, for complete restoration including replacement of trees, shrubs, topsoil, grass, etc. to the satisfaction of the Departmental Representative and ESO.

.5 Construction equipment will not be cleaned in any watercourse.

1.14 WILDLIFE

.1 During the Environmental Briefing all personnel shall be instructed by the ESO on procedures to follow in the event of wildlife appearance near or within the work site and any other wildlife concerns. This briefing will include a bear-safety orientation and procedures.

.2 If necessary, the construction activity may be scheduled around important wildlife windows. Specific windows involve fish. The Departmental Representative will advise if any apply.

.3 Workers will carry bear-spray on the trail and at the work site and will watch for bird nests or and chicks so as not to step on them.

.4 A respectful distance will be maintained from all large mammals: minimum 30m for ungulates and 100m for bears.

.5 Avoid or terminate activities on site that attract or disturb wildlife and vacate the area and stay away from the immediate location if bears, cougars, wolves, elk or moose display aggressive behaviour or persistent intrusion. Such encounters are to be immediately reported to the Duty Officer (867 695 3732). Extra care to control materials that might attract wildlife (e.g. lunches and food scraps) must be exercised at all times (i.e. must be stored in bear-proof canisters). Cooking will not be permitted at the work site.

.6 Notify the ESO and Departmental Representative immediately about dens, litters, nests, carcasses, bear activity or encounters on or around the site or crew accommodation (within 250m). Other wildlife related encounters are to be reported within 24 hours. If either the ESO or Departmental Representative are not available, NNPR Duty Officer will be contacted at (867) 695 3732.

.7 The feeding, harassment or destruction of wildlife will be strictly prohibited and will be grounds for employee dismissal from the work.

1.15 POLLUTION CONTROL

.1 Maintain temporary erosion and pollution control features installed under this Contract.

.2 The Contractor shall prevent any deleterious and objectionable materials from entering streams, rivers, wetlands, water bodies or watercourses that would result in damage to aquatic and riparian habitat. Hazardous or toxic products shall be stored no closer than 100 metres from the Rabbitkettle River.

.3 A Spill Response Plan will be prepared as part of the EPP and shall detail the containment and storage, security, handling, use and disposal of empty containers, surplus product or waste generated in the application of these products, to the satisfaction of the Departmental Representative and the ESO and in accordance with all applicable federal and provincial legislation. The EPP shall include a list of products and materials to be used or brought to the construction site that are considered or defined as hazardous or toxic to the environment. Such products include, but are not limited to, waterproofing agents, grout, cement, concrete finishing agents, hot poured rubber membrane materials, asphalt cement and sand blasting agents.

.4 The containment, storage, security, handling, use, unique spill response requirements and disposal of empty containers, surplus product or waste generated in the use of any hazardous or toxic products shall be in accordance with all applicable federal and territorial legislation.

.5 The Contractor shall prevent blowing dust and debris by covering and/or providing dust control for on-site work by methods that are approved by the Departmental Representative or ESO.

.6 The Contractor shall provide spill kits at re-fuelling, lubrication, and repair locations that will be capable of dealing with 110% of the largest potential spill and shall be maintained in good working order on the construction site. The ESO and Departmental Representative prior to project start-up must approve these spill kits. The Contractor and site staff shall be informed of the location of the spill response kit(s) and be trained in its use.

.7 Timely and effective action shall be taken to stop, contain and clean-up all spills as long as the site is safe to enter. The Departmental Representative and the ESO shall be notified immediately of any spill. If not available, NNPR Duty Officer will be contacted at 867 695 3732.

.8 In the event of a major spill, all other work shall be stopped and all personnel devoted to spill containment and clean-up.

.9 The costs involved in a spill incident (the control, clean up, disposal of contaminants and site remediation to pre-spill condition), shall be the responsibility of the Contractor. The site will be inspected to ensure completion to the expected standard and to the satisfaction of the Departmental Representative and ESO.

1.16 HISTORICAL/ ARCHAEOLOGICAL CONTROL

.1 Artifacts, relics, antiquities and items of historical interest found on the work site shall be left undisturbed and reported to the ESO or Departmental Representative immediately. The Contractor and workers shall wait for instructions before proceeding with their work.

.2 All historical or archaeological objects found in Nahanni National Park Reserve are protected under the National Parks Act and Regulations and are the property of Parks Canada. The Contractor and workers shall protect any articles found and request direction from the ESO or the Departmental Representative.

1.17 WASTE MATERIALS STORAGE AND REMOVAL

.1 The Contractor and workers shall dispose of hazardous wastes in conformance with the Canadian Environmental Protection Act.

.2 All wastes originating from construction, trade, hazardous and domestic source, shall not be mixed, but will be kept separate.

.3 Construction, trade, hazardous waste and domestic waste materials shall not be burned, buried, or discarded at the construction site or elsewhere in Nahanni National Park Reserve. These wastes shall be contained and removed in a timely and approved manner by the Contractor and workers, and disposed of at an appropriate waste landfill site or recycler located outside the park. Construction waste storage containers, provided by the Contractor, shall be emptied by the Contractor when 90% full. Waste containers will have lids, and waste loads shall be covered while being transported.

.4 A concerted effort shall be made by the Contractor and Workers to reduce, reuse, and recycle materials.

.5 All efforts to prevent wildlife from obtaining food, garbage, or other domestic wastes shall be made by the Contractor and contract staff while undertaking their work in Nahanni National Park Reserve. Such wildlife attractants shall not be stored at the work site overnight. Lunches, coolers and food products, including waste food products, shall be securely stored away from access by animals. Daily storage of food scraps, food wrappers, pop cans or other attractive products in bear proof containers is mandatory. Storage of food and domestic wastes (including work site waste) on the food cache at Rabbitkettle Lake will be required. It is incumbent on the Contractor to have all domestic wastes removed from the park.

.6 The Contractor and workers shall immediately report any circumstances related to food/garbage (e.g. overflowing container or strong smell) and wildlife to the ESO or the Departmental Representative. If neither can be reached, the Contractor/worker shall immediately contact NNPR Duty Officer (867) 695 3732 and report the details.

.7 Sanitary facilities, such as a portable container toilet, shall be provided by the Contractor and maintained in a clean condition.

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 CLEARING AND GRUBBING

Clearing is not expected, but if it is required for placement of the north shore anchor, the following considerations will be met.

.1 The Contractor shall ensure that the substrate of riparian area of streams, rivers or watercourses, whether open water or frozen over shall not be disturbed by tracked, wheeled, or self-propelled equipment. The ESO or Departmental Representative will provide direction in the case of work occurring near any wetland area or watercourses.

.2 The Contractor shall take all measures to ensure trees do not fall into streams, rivers, wetlands or water bodies or outside the clearing limits as marked by coloured flagging. Generally, work within a 30 meter buffer of watercourses, water bodies or wetlands requires the close oversight of the ESO or the Departmental Representative.

.3 Trees inadvertently felled into streams, rivers, watercourses or outside the clearing limits shall be removed by means so as to not damage the substrate or any standing trees left outside the clearing limits. Machinery shall not go outside the clearing limits, or into streams, rivers, watercourses or water bodies to remove felled trees.

.4 Logs and other salvage materials are to be conveyed to and placed in the storage site without spread of debris or damage to other standing trees or landscape resources outside the marked clearing or storage limits. They shall not be skidded through wetlands, waterways, or water bodies. Felled trees will either remain on site for future use, or be heli-slung to the staff cabin at Gahnîhthah Mîe and bucked, as directed by the Departmental Representative.

.5 During the grubbing component, stumps, roots, embedded logs and other non-soil debris shall be pulled and shaken free of loose soil and rocks before being chopped up and distributed in the vegetation.

.6 Topsoil removed for excavation at the anchor sites will be used to rehabilitate the sieraaslope basket anchors.

.7 Existing areas or vegetation disturbed as a result of this contract shall be rehabilitated using approved topsoil from the park and a native grass seed mix as specified by the Departmental Representative or the ESO.

.8 Any vegetation debris will be scattered flush to the ground out of sight in surrounding vegetation at least 5m from the trail and will be sufficiently scattered to avoid accumulations exceeding 5cm in depth.

.9 Consideration will be given to ensure vegetation debris does not increase fire risks.

3.02 STRIPPING

.1 A contingency plan for control of dust generated from the construction site shall be prepared, with materials availability arranged in the event of their need. In the event of a work program shutdown during inclement weather, erosion control of bared soils or excavated materials stockpiles will be required. The Contractor's EPP will describe measures to be implemented in such circumstance.

.2 Stripping close to any watercourse, water body or wetland shall employ methods to ensure materials are not pushed, fall or are eroded into the water or wetlands. Generally, work within a 30 meter buffer of waterways or wetlands require the close oversight of the ESO and the Departmental Representative.

.3 No stripping shall occur outside of the designated area or within 1 meter of the drip line of existing forest.

.4 Stripped soil materials shall be placed and stored at locations and in amounts and form as instructed by the Departmental Representative, for later reclamation use on graded slopes. Stripping piles may require erosion control, sedimentation protection or stabilization, depending on the location and anticipated duration of storage. At the Departmental Representatives direction, the Contractor shall prepare a plan for management of each stripping pile.

3.03 EXCAVATION AND PLACEMENT

.1 Excavation will be undertaken to the construction drawings.

.2 All sediment control measures shall be implemented by the Contractor prior to the commencement of work in the vicinity of any water bodies, watercourses or wetlands.

.3 If a pump-out sump to dewater excavations will be required, the Contractor is to prepare an EPP which details how the dewatering shall be undertaken, to the satisfaction of the Departmental Representative and the ESO. Water containing suspended materials shall not be pumped into watercourses, drainage system or on to land, except with the permission of the Departmental Representative and ESO.

3.04 SPECIFIC CONCERNS RELATIVE TO EROSION CONTROL AND SEDIMENTATION

.1 The Contractor shall prepare an Erosion and Sedimentation Management Plan for the components of the contract that are undertaken in proximity to watercourses, wetlands, or riparian environments. This plan shall be to the satisfaction of the Departmental Representative and ESO.

.2 An important desired end result is to allow no release into watercourses of sediments in levels that are deleterious to fish or that would harmfully alter, disrupt, or destroy fish habitat. Similarly, there is to be no sediment release into areas of vegetation growth or sensitive areas of sediments in levels that would adversely alter growing or hydraulic conditions.

.3 Excavation at anchor and borrow sites will not exceed a 2m diameter or 1m depth and no holes or craters will be created. Natural contours of borrow sites will be maintained or returned to normal when work is completed.

.4 Duff, topsoil and vegetation removed from the anchor sites will be used to rehabilitate the sites (the sierraslope anchors baskets).

.5 Backfill materials will not be sourced from below hiking trails or high banks to prevent destabilization of the bank.

3.05 SPECIFIC CONCERNS RELATED TO FISH

.1 In-stream works are not required and natural woody debris, rocks, sand or other materials will not be removed from the banks or shoreline of the Rabbitkettle River below the ordinary high water mark.

.2 Backfill material in addition to that excavated from anchor sites will be preferentially collected from the gravel bars and banks of inactive river channels to prevent impacts to fish and their habitat. The ESO or Departmental Representative will provide locations to the Contractor. Timing windows for fish species may apply in the event that backfill needs to be sourced from dry gravel beds below the high water mark (July 16 - August 14).

.3 Work will be scheduled to avoid wet, windy and rainy periods that may increase erosion and sedimentation.

.4 Approaches to the Rabbitkettle River will perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation.

.5 No rock, silt, sand, petroleum product, lumber, vegetation, debris, domestic waste, or any deleterious substance will be placed or dispersed into any water course or standing waterbody.

.6 Construction equipment will not be cleaned in any watercourse.

.7 Clearing of riparian vegetation will be avoided and no effect to shoreline vegetation is expected: existing trails and cleared areas will be used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Not used.

1.02 REFERENCES

.1 Within text of each specifications section, reference may be made to reference standards.

.2 Conform to these reference standards, in whole or in part as specifically requested in specifications.

.3 If there is question as to whether products or systems are in conformance with applicable standards, Departmental Representative reserves right to have such products or systems tested to prove or disprove conformance.

.4 Cost for such testing will be born by Departmental Representative in event of conformance with Contract Documents or by Contractor in event of non-conformance.

.5 Conform to latest date of issue of referenced standards in effect on date of submission of Tenders, except where specific date or issue is specifically noted.

1.03 QUALITY

.1 Products, materials, equipment and articles incorporated in Work shall be new, not damaged or defective, and of best quality for purpose intended. If requested, furnish evidence as to type, source and quality of products provided.

.2 Defective products, whenever identified prior to completion of Work, will be rejected, regardless of previous inspections. Inspection does not relieve responsibility, but is precaution against oversight or error. Remove and replace defective products at own expense and be responsible for delays and expenses caused by rejection.

.3 Should disputes arise as to quality or fitness of products, decision rests strictly with Departmental Representative based upon requirements of Contract Documents.

1.04 AVAILABILITY

.1 Immediately upon signing Contract, review product delivery requirements and anticipate foreseeable supply delays for items. If delays in supply of products are foreseeable, notify Departmental Representative of such, in order that substitutions or other remedial action may be authorized in ample time to prevent delay in performance of Work.

.2 In event of failure to notify Departmental Representative at commencement of Work and should it subsequently appear that Work may be delayed for such reason, Departmental Representative reserves right to substitute more readily available products of similar character, at no increase in Contract Price or Contract Time.

1.05 STORAGE, HANDLING AND PROTECTION

.1 Handle and store products in manner to prevent damage, adulteration, deterioration and soiling and in accordance with manufacturer's instructions when applicable.

.2 Store packaged or bundled products in original and undamaged condition with manufacturer's seal and labels intact. Do not remove from packaging or bundling until required in Work.

.3 Store products subject to damage from weather in weatherproof enclosures.

.4 Store cementitious products clear of earth or concrete floors, and away from walls.

.5 Keep sand, when used for grout or mortar materials, clean and dry. Store sand on wooden platforms and cover with waterproof tarpaulins during inclement weather.

.6 Store sheet materials, lumber and miscellaneous metals on flat, solid supports and keep clear of ground. Slope to shed moisture.

.7 Store and mix paints in heated and ventilated room. Remove oily rags and other combustible debris from site daily. Take every precaution necessary to prevent spontaneous combustion.

.8 Remove and replace damaged products at own expense and to satisfaction of Departmental Representative.

.9 Touch-up damaged factory finished surfaces to Departmental Representative's satisfaction. Use touch-up materials to match original. Do not paint over name plates.

1.06 TRANSPORTATION

.1 Pay costs of transportation of products required in performance of Work.

1.07 MANUFACTURER'S INSTRUCTIONS

.1 Unless otherwise indicated in specifications, install or erect products in accordance with manufacturer's instructions. Do not rely on labels or enclosures provided with products. Obtain written instructions directly from manufacturers.

.2 Notify Departmental Representative in writing, of conflicts between specifications and manufacturer's instructions, so that Departmental Representative will establish course of action.

.3 Improper installation or erection of products, due to failure in complying with these requirements, authorizes Departmental Representative to require removal and re-installation at no increase in Contract Price or Contract

Time.

1.08 QUALITY OF WORK

.1 Ensure Quality of Work is of highest standard, executed by workers experienced and skilled in respective duties for which they are employed. Immediately notify Departmental Representative if required Work is such as to make it impractical to produce required results.

.2 Do not employ anyone unskilled in their required duties. Departmental Representative reserves right to require dismissal from site, workers deemed incompetent or careless.

.3 Decisions as to standard or fitness of Quality of Work in cases of dispute rest solely with Departmental Representative, whose decision is final.

1.09 CO-ORDINATION

.1 Ensure co-operation of workers in laying out Work. Maintain efficient and continuous supervision.

1.10 CONCEALMENT

.1 The Departmental Representative will inspect all work prior to any concrete pours. The Contractor shall notify the Departmental Representative 24 hours before any pour for inspection .

1.11 REMEDIAL WORK

.1 Perform remedial work required to repair or replace parts or portions of Work identified as defective or unacceptable. Co-ordinate adjacent affected Work as required.

.2 Perform remedial work by specialists familiar with materials affected. Perform in a manner to neither damage nor put at risk any portion of Work.

1.12 FASTENINGS

.1 Provide metal fastenings and accessories in same texture, colour and finish as adjacent materials, unless indicated otherwise.

.2 Prevent electrolytic action between dissimilar metals and materials.

.3 Use non-corrosive hot dip galvanized steel fasteners and anchors for securing exterior work, unless stainless steel or other material is specifically requested in affected specification Section.

.4 Space anchors within individual load limit or shear capacity and ensure they provide positive permanent anchorage. Wood, or any other organic material plugs are not acceptable.

.5 Keep exposed fastenings to a minimum, space evenly and install neatly.

.6 Fastenings which cause spalling or cracking of material to which anchorage is made are not acceptable.

1.13 PROTECTION OF WORK IN PROGRESS

.1 Do not cut, drill or sleeve load bearing structural member, unless specifically indicated without written approval of Departmental Representative.

1.14 EXISTING UTILITIES

.1 Protect, relocate or maintain existing active services. When services are encountered, cap off in manner approved by authority having jurisdiction. Stake and record location of capped service.

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 NOT USED

.1 Not Used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Section 01 35 43 - Environmental Procedures.

.2 Section 01 77 00 - Closeout Procedures.

1.02 MEASUREMENT PROCEDURES

.1 This work shall be incidental to the Contract and will not be measured for payment.

1.03 PROJECT CLEANLINESS

.1 Maintain Work in tidy condition, free from accumulation of waste products and debris, including that caused by Owner or other Contractors.

.2 Remove waste materials from site at daily regularly scheduled times or dispose of as directed by Departmental Representative. Do not burn waste materials on site.

.3 Make arrangements with and obtain permits from authorities having jurisdiction for disposal of waste and debris.

.4 Provide on-site bear proof containers for collection of waste materials and debris.

.5 Dispose of waste materials and debris off site outside the Park.

.6 Store volatile waste in covered metal containers, and remove from premises at end of each working day.

.7 Provide adequate ventilation during use of volatile or noxious substances. Use of building ventilation systems is not permitted for this purpose.

.8 Use only cleaning materials recommended by manufacturer of surface to be cleaned, and as recommended by cleaning material manufacturer.

1.04 FINAL CLEANING

.1 When Work is Substantially Performed remove surplus products, tools, construction machinery and equipment not required for performance of remaining Work.

.2 Remove waste products and debris other than that caused by others, and leave Work clean and suitable for occupancy.

.3 Prior to final review remove surplus products, tools, construction machinery and equipment.

.4 Remove waste products and debris including that caused by Owner or other Contractors.

.5 Remove waste materials from site at regularly scheduled times or dispose of as directed by Departmental Representative. Do not burn waste materials on site.

.6 Make arrangements with and obtain permits from authorities having jurisdiction for disposal of waste and debris.

.7 Inspect finishes , and ensure specified workmanship and operation.

.8 Sweep and wash clean paved areas.

.9 Remove dirt and other disfiguration from exterior surfaces

.10 Clean drainage systems

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 NOT USED

.1 Not Used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Section 01 74 11 - Cleaning.

.2 Section 01 78 00 - Closeout Submittals.

1.02 MEASUREMENT PROCEDURES

.1 This work shall be incidental to the Contract and will not be measured for payment.

1.03 ADMINISTRATIVE REQUIREMENTS

.1 Acceptance of Work Procedures:
- .1 Contractor's Inspection: Contractor: conduct inspection of Work, identify deficiencies and defects, and repair as required to conform to Contract Documents.
  - .1 Notify Departmental Representative in writing of satisfactory completion of Contractor's inspection and submit verification that corrections have been made.
  - .2 Request Departmental Representative inspection.
- .2 Departmental Representative Inspection:
  - .1 Departmental Representative and Contractor to inspect Work and identify defects and deficiencies.
  - .2 Contractor to correct Work as directed.
- .3 Final Inspection:
  - .1 When completion tasks are done, request final inspection of Work by Departmental Representative, and Contractor.
  - .2 When Work incomplete according to Departmental Representative, complete outstanding items and request re-inspection.

1.04 FINAL CLEANING

.1 Clean in accordance with Section 01 74 11 - Cleaning.
- .1 Remove surplus materials, excess materials, rubbish, tools and equipment.

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 NOT USED

.1 Not Used.

END OF SECTION

1 GENERAL

1.01 RELATED REQUIREMENTS

.1 Section 01 33 00 - Submittal Procedures.

.2 Section 01 77 00 - Closeout Procedures

1.02 MEASUREMENT PROCEDURES

.1 This work shall be incidental to the Contract and will not be measured for payment.

1.03 AS -BUILT DOCUMENTS AND SAMPLES

.1 Maintain, in addition to requirements in General Conditions, at site for Departmental Representative one record copy of:
  .1 Contract Drawings.
  .2 Specifications.
  .3 Addenda.
  .4 Change Orders and other modifications to Contract.
  .5 Reviewed shop drawings, product data, and samples.
  .6 Field test records.
  .7 Inspection certificates.
  .8 Manufacturer's certificates.

.2 Store record documents and samples in field office apart from documents used for construction.

.3 Label record documents and file in accordance with Section number listings in List of Contents of this Project Manual.
  .1 Label each document "PROJECT RECORD" in neat, large, printed letters.

.4 Maintain record documents in clean, dry and legible condition.
  .1 Do not use record documents for construction purposes.

.5 Keep record documents and samples available for inspection by Departmental Representative.

1.04 RECORDING INFORMATION ON PROJECT RECORD DOCUMENTS

.1 Record information on set of black line opaque drawings, and in copy of Project Manual.

.2 Record information concurrently with construction progress.
  .1 Do not conceal Work until required information is recorded.

.3 Contract Drawings and shop drawings: mark each item to record actual construction, including:
  .1 Field changes of dimension and detail.
  .2 Changes made by change orders.
  .3 Details not on original Contract Drawings.
  .4 References to related shop drawings and modifications.

.4 Specifications: mark each item to record actual construction, including:
  .1 Changes made by Addenda and change orders.

.5 Other Documents: maintain inspection certifications and field test records required by individual specifications sections.

1.05 FINAL SURVEY

.1 Submit final site survey certificate certifying that elevations and locations of completed Work are in conformance, or non-conformance with Contract Documents.

1.06 WARRANTIES AND BONDS

.1 Submit, warranty information made available during construction phase, to Departmental Representative for approval prior to each monthly pay estimate.

.2 Assemble approved information in binder, submit upon acceptance of work and organize binder as follows:
  .1 Separate each warranty or bond with index tab sheets keyed to Table of Contents listing.
  .2 List subcontractor, supplier, and manufacturer, with name, address, and telephone number of responsible principal.
  .3 Obtain warranties and bonds, executed in duplicate by subcontractors, suppliers, and manufacturers.
  .4 Verify that documents are in proper form, contain full information, and are notarized.
  .5 Co-execute submittals when required.
  .6 Retain warranties and bonds until time specified for submittal.

.3 Except for items put into use with Owner's permission, leave date of beginning of time of warranty until Date of Substantial Performance is determined.

2 PRODUCTS

2.01 NOT USED

.1 Not Used.

3 EXECUTION

3.01 NOT USED

.1 Not Used.

END OF SECTION

TETRA TECH EBA

GEOTECHNICAL AND HYDROTECHNICAL EVALUATION FOR REPLACEMENT OF RABBITKETTLE RIVER FERRYWAY, NAHANNI NATIONAL PARK RESERVE, NT

PRESENTED TO

Parks Canada Agency

JUNE 2014
ISSUED FOR USE
FILE: Y14103255-01

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EXECUTIVE SUMMARY

Tetra Tech EBA Inc. (Tetra Tech EBA) has carried out a geotechnical engineering evaluation and a hydrotechnical evaluation for a proposed replacement ferryway at Rabbitkettle River in Nahanni National Park Reserve, NT, for Parks Canada Agency (Parks Canada).

The main objectives of the work were to confirm the geotechnical and hydrotechnical site conditions and to provide information for the preparation of drawings and specifications for construction of the foundations and structural elements of the proposed replacement ferryway. This report discusses the findings at the project site provides recommendations for the foundations and anchors proposed for use at this remote site. The report also includes recommendations and options for erosion protection along the river bank on the north side of the ferryway system.

Tetra Tech EBA prepared a terrain map based on the analysis of existing aerial photo coverage. The terrain map and existing site data were used as guides for the site reconnaissance, and the results of the site reconnaissance were used to update the map. The terrain map was also used to help provide additional information regarding existing and potential natural hazards at the ferryway site, including the likelihood of future riverbank erosion and the potential for debris to impact the ferryway system.

Surficial conditions at the site were verified based on observations during the field work, including observations of terrain, vegetation, apparent soil movements, and exposures of soil in the riverbanks. Subsurface conditions were examined to shallow depths only, due to winter conditions and hard-frozen ground. However, overall soil conditions appeared to be similar to those encountered by previous investigators, and some further information about soil stratigraphy was obtained from the river bank soil exposures. Information was also collected on the stream characteristics for the purpose of the hydrotechnical evaluation, including the characteristics of materials in areas of apparent deposition and the overall stream geometry.

Tetra Tech EBA determined that while the south river bank did not appear to be experiencing significant erosion, the north bank had been undercut by about 0.9 m, and the shoreline appeared to have retrogressed at the ferryway location. Because the size of material in the gravel beds appeared to be insufficient for use as riprap, alternative ideas were required to mitigate the potential for future erosion at the ferryway crossing.

The limitations and problems associated with the previous iterations of foundations and anchors were noted, and alternatives were developed to mitigate those issues in the new proposed foundations for the cable supports and the cable anchors. The detailed design for the cable supports and anchors was developed with the structural engineering team and the Parks Canada operations and assets teams. The remoteness of the project site, the low number of users, the overall success of previous ferryway operations at the site, and the operational limitations of the ferryway system were considered in the design of the system. The design was refined to suit the operational needs of Parks Canada, while incorporating provisions to improve operational safety and help protect Parks Canada's capital investment. It is understood that, in order to satisfy operational requirements, Parks Canada accepts the risks of allowing a smaller minimum recommended freeboard (1.0 m instead of 1.5 m), as well as accepting the risks associated with the possibility that the minimum recommended freeboard of 1.0 m during either operations (estimated at Q2 or less) or spring flood or storm events (estimated at up to Q100) may not always be satisfied. In the event that high water levels, a capsized boat, and/or debris result in overloading of the cable system, a shear pin in the cable mounting apparatus is proposed in order to release the cable and protect the cable supports and anchors against overloading. Whether or not the boat is capsized (thus far never experienced), the release of either cable end should also allow the boat to drift to shore rather than being stuck at the middle of its trajectory.

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Parks Canada Agency and their agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Parks Canada Agency, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's General Conditions provided in Appendix A of this report.

1.0 INTRODUCTION

1.1 General

Tetra Tech EBA Inc. (Tetra Tech EBA) has carried out a geotechnical engineering evaluation and a hydrotechnical evaluation for a proposed replacement ferryway at Rabbitkettle River in Nahanni National Park Reserve, NT, for Parks Canada Agency (Parks Canada). The evaluations are to support the foundation design and structural engineering design of the replacement structure. The work scope was in accordance with our proposal letter of January 12, 2014 (Reeves, Kors-Olthof) and was authorized under Contract No. 5P420-13-5170. The work was a follow-up to an evaluation carried out by Carswell Consulting Engineers Ltd. (Carswell) and Sabatini Earth Technologies Inc. (SETI) in 2010.

The main objectives of the work were to confirm the geotechnical and hydrotechnical site conditions and to provide information for the preparation of drawings and specifications for construction of the foundations and structural elements of the proposed replacement ferryway. This report discusses the findings at the project site and provides foundation recommendations as well as recommendations for erosion protection. This issued-for-review report provides an opportunity for discussion of foundation and erosion protection options to allow the most suitable options to be further developed for use at this remote site.

1.2 Project Details

Tetra Tech EBA understands that the existing ferryway is to be replaced by a new ferryway, incorporating essentially the same concept as before. As stated in the Project Brief from Parks Canada, the existing system uses a boat that is attached to the main crossing cable which is supported by a structural steel support system with guy cables. The boat is moved along the cable by someone on shore using a pulley system. The purpose of the system is to allow park visitors accompanied by Parks Canada staff to safely cross the Rabbitkettle River to hike on tufa mounds, large calcareous mounds created by upwelling hot springs south of the river (Figure 1). The existing ferryway structure is more than 20 years old and the cable is no longer serviceable.

In addition to the ferryway design, the work entails a rough site grading plan and a bank erosion assessment, with recommendations for erosion protection to be provided as necessary.

Construction drawings and specifications are to be completed so as to facilitate the tendering of the project, start of construction in July 2014 and completion of the project by Autumn 2014.

1.3 Scope of Work

Tetra Tech EBA understood the scope of work for the initial geotechnical and hydrological to be as follows:

- Geotechnical Engineering :
  - Obtain an understanding of existing site conditions, including soils, groundwater and/or permafrost conditions;
  - Evaluate geotechnical conditions and prepare recommendations for design and construction of suitable support structures and footings for cable ends;
  - Evaluate geotechnical conditions and prepare recommendations for design and construction of suitable anchor types;
  - Evaluate erosion conditions at the river banks and provide recommendations if/as needed for river bank

protection. Provide a rough site-grading plan in the area of the site as applicable to the design and construction of river bank protection.

- Hydrotechnical Engineering: Obtain hydrotechnical information for the site, including an estimate of the stream velocity, in order to assist in the determination of the following parameters:
  - Drag force on the boat for the design of cables and fasteners; and
  - Nominal size of erosion protection, if/as applicable.

Additional geotechnical engineering-related scope items as listed in the proposal of January 12, 2014 are to be addressed in conjunction with structural engineering input.

2.0 METHODOLOGY

2.1 General

The above-listed scope items were addressed by two disciplines: geotechnical engineering and hydrotechnical engineering. A more complete understanding of the site conditions was required for the completion of an appropriate design of the ferryway. Tetra Tech EBA carried out the following tasks to improve our understanding of the site:

- Reviewed site information, conduct terrain analysis and mapping based on available air photos and existing site data;
- Based on the results of the site information review, as well as the terrain analysis and mapping, conducted ground-truthing via site reconnaissance;
- Obtained general river cross-section data as feasible depending upon river, snow and access conditions, in support of the hydrotechnical evaluation;
- Obtained samples of possible borrow/fill materials, river bank slope and beach soils, and soils near the existing cable posts, using hand-held equipment;
- Carried out laboratory testing of samples collected during the site investigation; and
- Prepared this evaluation report that describes the findings from the terrain analysis and mapping, as well as the ground-truthing, site reconnaissance and cross-section data, with recommendations for suitable foundations, anchors, and erosion protection based on site observations.
- Where site findings indicated that alternative design solutions would be appropriate or beneficial to the project, Tetra Tech EBA would provide recommendations for these solutions as well. If site findings indicate that further information is required for successful completion of the project, Tetra Tech EBA will provide recommendations for further study.

The following sections describe Tetra Tech EBA's methodology in carrying out the above-listed scope and task items.

2.2 Site Information Review

Tetra Tech EBA reviewed the information available from Parks Canada about the site, including a previous geotechnical and structural evaluation for the site, aerial photos, site photos and oblique aerial photos from a helicopter provided by Parks Canada, as well as geology and surficial geology mapping. A complete list of references is attached.

2.3 Terrain Analysis and Mapping

Tetra Tech EBA prepared a preliminary terrain map based on the analysis of existing aerial photo coverage. Three original hard copies of air photos were borrowed from Parks Canada. Two of these air photos were scanned at high resolution and then georeferenced in order to create digital copies suitable for use in *PurVIEW*, a software package facilitating stereoscopic analysis and mapping. The digital photos were loaded into *PurVIEW* for 3D visualization on the computer screen. Two of the main advantages of using *PurVIEW* are:

- Excellent georeferencing, resulting in spatially-accurate mapping; and
- The ability to zoom in and out to determine more accurately what surficial geology and permafrost features are present.

The surficial geology surrounding Rabbitkettle River, including the area of the ferry crossing, was mapped. The photos used for the project are shown in Table 2.3-1.

Table 2.3-1: Air Photos Used for Terrain Study

Year	Scale	NAPL Roll Number	Photo Numbers	Photo Type
1976	1:30,000	A24523	216, 217	Hi-res Scans

The terrain map and existing site data were used as guides for the site reconnaissance. The terrain mapping is reconnaissance level and most of the materials, terrain and processes are interpreted from air photograph interpretation only with no field-checking (Figure 1). The results are therefore preliminary, and cannot be verified without field-checking and thus are not intended for use in development planning. Only the ferryway crossing area was field-checked, and although only limited soil stratigraphy could be explored due to winter conditions, that area is considered more reliable for planning purposes (Figure 2).

The terrain map was also intended to help provide additional information regarding existing and potential natural hazards at the ferryway site, including the likelihood of future riverbank erosion.

2.4 Site Investigation

The purpose of the site investigation was to conduct ground-truthing and site reconnaissance to support the terrain analysis and mapping, and to confirm or supplement the information provided by the previous geotechnical site investigation carried out by Sabatini Earth Technologies Inc. (Sabatini, 2010).

Mr. Tim Schaap, E.I.T., of Tetra Tech EBA traveled to the Rabbitkettle River crossing site on March 4 and 5, 2014 via helicopter out of Fort Simpson, NT, assisted by Parks Canada staff. Numerous photos were obtained from various vantage points at and near the existing ferryway location, as well as oblique aerial overview photos from the helicopter (Photos 1 through 12).

Additional details of river channel behaviour could be discerned on the ground and from the helicopter, further assisting in refining the terrain map and understanding the site conditions at the ferryway. Though observations were significantly limited by snow cover, Tetra Tech EBA was able to gather some useful information about overall stream configuration, deposition and erosion areas, as well as variations in width and depth.

Due to the remoteness of the site and the high cost of bringing in drilling or excavating equipment, only very limited shallow drilling was possible during the site investigation through the use of a hand-held, cordless hammer drill and hand tools. Several shallow testholes were drilled and/or dug near the existing cable support posts on either side of the Rabbitkettle River, on the beach and/or toes of the river banks, and on the gravel beds exposed at low water.

A second day of site investigation was lost due to mechanical issues facing the helicopter related to the extremely cold air temperatures.

2.5 Laboratory Testing

Samples collected during the site reconnaissance were returned to Tetra Tech EBA's Yellowknife laboratory. Testing was done for the purposes of classification and determination of engineering properties. Basic laboratory testing consisted of natural moisture content and soil gradation. Atterberg Limit determinations were not carried out, as visual inspection revealed the samples to be non-plastic. One sample suitable for water soluble sulphate content testing was sent on to Tetra Tech EBA's Calgary laboratory. The soluble sulphate content result would assist in evaluating requirements for foundation cement type if/as needed. No porewater salinity tests were done, since the depths investigated were too shallow to have encountered permafrost.

2.6 Hydrotechnical Analysis

Tetra Tech EBA performed hydrotechnical analysis of the Rabbitkettle River in the vicinity of the ferryway. The analysis comprised two main components:

- a hydrologic assessment employing regional analysis to predict the flow at the site for a specified return period; and
- a hydraulic assessment of the river reach to estimate the water surface elevation and water velocity for a specified flow.

In addition, we estimated the maximum force that may be exerted by the water on the boat using the drag force equation.

3.0 SITE DESCRIPTION

3.1 Location

The project site is located roughly 1.6 km upstream of the mouth of the Rabbitkettle River, and just east of the Rabbitkettle Tufa Mounds, at approximately Latitude 61.944155° North and Longitude 127.177199° West (Figure 1). The site is accessible by air using small fixed wing aircraft on floats or skis to land on Rabbitkettle Lake about 3 km northwest of the site, or by helicopter to land on a gravel bar on the north side of the river during winter low river water levels. A 3.5 km trail leads from Rabbitkettle Lake to the ferryway crossing on the north side of the Rabbitkettle River, and from the Tufa Mounds to the south side of the river. During summer, visitors can also arrive at Rabbitkettle Lake (from further upstream on the South Nahanni River) and/or depart from the Rabbitkettle Lake area via canoe, kayak or raft.

3.2 Regional Setting and Climate

According to the Government of the Northwest Territories, Environment and Natural Resources, Ecosystem Classification Report for the Cordillera, the project site is situated within the Boreal Cordillera, in the Ragged Range Valley Mid-Boreal zone.

Trends in climate are anticipated to be similar to the climate in Fort Simpson since it is nearly at the same latitude;

however, some differences in absolute temperature are expected as a result of local mountain climate variations as well as the difference in elevation.

Climate data for Fort Simpson has been available since 1964 and is taken for the purpose of this study to be the closest approximation of climate at Rabbitkettle River ferryway site. The mean annual temperature in the Nahanni Plateau Ecoregion is reported as approximately -5°C (Ecological Framework of Canada), but the timeframe of measurement is not defined. Over the period of record at Fort Simpson, the mean annual air temperature has averaged -3.1°C. However, the climate has exhibited a warming trend over that time. The mean annual air temperature has averaged -2.6°C over the 30 years ending 2012. Over the period of record, the rate of warming has averaged 0.06°C per year. This warming has come about primarily as a decrease in winter temperatures, and summer temperatures have remained more consistent.

3.3 Geology

The bedrock geology of the area was mapped by Gabrielse et al (1972). The Rabbitkettle River at the ferry crossing is shown as covered with Quaternary sediments but the underlying rocks, depending on the location of the boundary beneath the Quaternary cover, are either part of the Road River Formation or the Sunblood Formation. The Road River Formation is Ordovician, Silurian and Lower Devonian in age. It consists of black pyritic shale, black argillaceous limestone, green shaly limestone, grey and black chert, calcareous siltstone and black cherty dolomite. The Sunblood Formation is Upper Ordovician to Silurian and consists of grey dolomite, pink limestone and orange-brown sandstone.

Locally, the Rabbitkettle Tufa Mounds are of Holocene age and are actively being formed on the south side of the Rabbitkettle River. The mounds are a visitor attraction, and the reason for the installation of the original ferryway and the proposed replacement.

Soil types were mapped by Gabrielse et al only as Quaternary unconsolidated glacial and alluvial deposits.

As discussed in Section 2.3 above, Figure 1 presents Tetra Tech EBA's terrain analysis and mapping for the area, differentiating the locations and extents of probable or proven terrain types, and the associated bedrock and soil types. Figure 2 provides further detail in the area immediately surrounding the project site.

3.4 Surface Conditions

Surface conditions were largely obscured by snow during the time of the site visit. Trees at the site are up to 30 cm in diameter. Species include both black and white spruce, birch, willow and alder.

Observations on the ground and from the air indicate a wide river valley containing a meandering stream that is subject to braiding, with some large overflow channels evident, including a large channel immediately north of the project site (Figures 1 and 2). Much of the valley formation would have taken place during deglaciation, followed by large sections of glaciofluvial sediment being cut away by the river, resulting in prominent headlands in many areas along the river, with flat wide floodplains in other areas where the present-day river has moved away from the slopes that it cut. Leading edges of islands or overflow channels, as well as local outside edges of low-water channels tend to be eroded, sometimes resulting in exposed near-vertical or undercut banks, and sometimes resulting in areas where erosion was not obvious due to snow cover, but where trees are leaning towards the river.

The floodplain on the north side of the river is relatively flat and about 2.0 m about the winter water level in the river. Erosion has undercut the bank at the north ferryway landing area by up to 0.9 m. A small channel that is evident at low water impinges directly on the location of the north ferryway landing, potentially contributing to year-round erosion. Observations of the area (and photos of the boat tied up in summer) suggest that the boat might also be contributing to erosion of the north river bank while it is tied up in the water (Figures 2 and 3). Trees in the vicinity of the steel post were typically 15 to 30 cm in diameter. Because of the snow cover, it was not possible to determine if there had been overflow onto the floodplain in recent years, but it is likely that this is the case at least some of the time in this active alluvial floodplain.

The south ferryway landing area appears to be more protected with a gentle beach area leading up to the south bank. The reason for this sheltered area is a zone of colluvial soil just upstream protruding a few metres into the river, likely creating an area of slower-moving water at the ferryway landing area (Figure 2, Photo 10). The south floodplain is also relatively flat, but narrower than the north floodplain, though it is 0.4 to 0.5 m higher in elevation (Figure 3).

Up to about 30 m upriver of the south cable, a slump zone / tension crack is mapped as Ct (Figures 1 and 2). The soil is sandy, ice is present near surface so the water table is assumed to be high (frozen), and there is seepage (ice) on the river bank (Photo 12). The land appears to be subsiding/creeping slowly towards the river, trees are leaning into the river (Photo 11), and a long, narrow pond seems to have formed a few metres from the riverbank, parallel to the river. The unit is thus probably a small slump block that originated on the fluvial terrace above. Summer water seepage through these sediments coupled with river erosion may have caused the failure. The water source is either the tufa mounds or the organic units to the southwest and south of the failed area of the river bank, respectively.

3.5 Geotechnical Subsurface Conditions

3.5.1 General

Beneath a thin organic layer (up to about 0.1 m thick), sands and silts were generally encountered on shore at the Rabbitkettle River. The following sections describe the findings near the existing cable posts, at the toes of the river banks and/or beaches, and in the gravel beds, as well as at the glaciofluvial deposit downstream.

3.5.2 Rabbitkettle River North Bank

The north bank of the Rabbitkettle River (left side if travelling downriver), has experienced about 0.9 m of undercut scour at a point between 4 and 5 m from the existing north steel post. This location is on the outer bend of the small meandering river channel visible at low water (Figure 2; Photos 4 through 7). The soil within the scour zone, about 1.2 to 1.5 m below grade, is predominantly composed of sand and silt with some organics. The moisture content was about 38% in a sample obtained from this area, which likely reflects the organic content, but may also be related to the proximity of the water table and some capillary action, and/or winter conditions with accompanying uptake and freezing of water. A gravel and sand layer was noted underlying the sandy silty soil. The gravel and sand had a soil moisture content of about 19%, also quite high. The gravel and sand layer may or may not continue beneath the floodplain area. The thickness of this gravel interbed was not determined and may be thin.

Test drilling to a depth of 0.4 m behind the steel post confirmed a silt with some sand, reasonably consistent with the findings reported in the Sabatini report (2010), in which silty sand, and sand and silt were noted a few metres northeast of the cable post. No soil moisture contents are available from the Sabatini boreholes.

3.5.3 Rabbitkettle River South Bank

The south bank, or right hand side facing downriver, was considered to be more protected from the river in its current configuration. A gravel bar and a sandy beach were present below the south river bank. The beach sand was fine-grained with some silt, dry near the surface and frozen solid below the upper few centimeters (Photo 3). The soil moisture content in this layer was about 12%. Deeper soils in the same area tended to contain more silt, and laboratory testing indicated a soil moisture content of about 22%. Test drilling beside the steel post revealed a sandy silt soil with some clay, once again reasonably consistent with the Sabatini findings (silty sand). Similar to the soils encountered at the north river bank, organics and water uptake due to winter conditions in this soil layer have likely affected the soil moisture content in the sample obtained, measured at about 80%.

To sum up, Tetra Tech EBA's findings in conjunction with Sabatini's findings suggest that the floodplain/terrace sediments are composed largely of silts and sands, with significant variability in the proportion of each constituent to be expected in this natural alluvial deposit. While a trace to some clay is also sometimes encountered within the silt/sand layers, observations suggest it is only a minor constituent in this area. At approximately the elevation of the winter water level, there is a sand/gravel layer which may or may not continue beneath the river banks on either side, but which was exposed in the erosion scour at the north bank.

3.5.4 Rabbitkettle River Gravel Bars

Coarser-grained sediments are generally indicative of faster-moving water, which is anticipated to be the case during seasonal high water in the vicinity of the gravel bars in the river. The gravel bars generally consisted of sand and gravel, trace cobbles, trace silt, grey/light blue, dry to damp, loose; rounded gravel/sand is medium to coarse-grained, with cobbles up to 120 mm diameter (Photos 1 and 2). The apparent areas of deposition in the river are mapped in Figure 2, and can be seen in Photos 7 and 8. It is understood that the northerly gravel bar is commonly used for helicopter landings at low water, as it was when Tetra Tech EBA visited the site.

3.5.5 Glaciofluvial Deposits

A glaciofluvial deposit has been mapped downstream of the ferryway site (Figures 1 and 2). Usually such deposits contain considerable gravel and medium to coarse-grained sand, but the slope segment that Tetra Tech EBA was able to visit appeared to consist largely of fine silty sand (Photos 7, 13 and 14). Further investigation would probably reveal significant variation in grain size in these deposits.

3.5.6 Bedrock

Bedrock was not encountered in the ferryway area, and though the depth of investigation was very limited, it is considered unlikely that bedrock will be encountered within the probable depth of construction. However, bedrock is present at the tufa mounds southwest of the site, upstream of the ferryway.

3.6 Groundwater Conditions

Groundwater conditions near the Rabbitkettle River are expected to closely follow the river water elevation, particularly if the gravel/sand layer does indeed extend under the river bank. Further inland, the water table will generally gain in elevation following the overlying terrain. Groundwater may be perched on top of seasonally frozen soils, or on the top of the permafrost, if/where present. Locally, the groundwater table daylights at ground surface, such as along the upslope edge of the colluvial terrace just upstream of the south ferryway access point, as described above under "Surface Conditions."

3.7 Permafrost Conditions

Permafrost was not encountered during the field work, as the seasonal frost was much too well-bonded to penetrate with the equipment at hand. The area is mapped as having extensive discontinuous permafrost with low ice content (Heginbottom, 1995). It is anticipated that locally silty soils may incorporate some ice lenses, while granular soils should have relatively low ice content. The river likely moderates the ground temperature, as well as providing a potential source of water for ice lens formation. Depending on the type of groundcover, thickness of organics soils, underlying soil types (fine-grained or coarse-grained), degree of site disturbance, and proximity to the river, the active layer is estimated at about 2 to 3 m thick.

3.8 Hydrotechnical Conditions

3.8.1 General

Tetra Tech EBA carried out hydrologic and hydraulic assessments for the ferryway site. The following paragraphs describe the analyses carried out and the results obtained for each assessment.

3.8.2 Hydrologic Assessment

Tetra Tech EBA performed a regional analysis to predict the peak instantaneous flows for various return periods in the Rabbitkettle River.

Regional analysis relies on gauged watercourses in the area that exhibit similar physiographic characteristics as our watershed of interest. We identified seven gauged watersheds and completed frequency analysis on the stream flow data for each watercourse. We plotted the results of watershed size vs. flow per unit area of watershed and completed a regression analysis to predict flows for the Rabbitkettle River.

Estimated flow values for various return periods are presented in Table 3.8.2-1. Using the hydraulic model discussed in Section 3.8.3 of this report, we predicted the water surface elevation associated with each flow. These values are also presented in Table 3.8.2-1.

Table 3.8.3-1: Summary of Estimated Water Levels at Rabbitkettle River Ferryway

Return Event	Flow (m^3/s)	Water Surface Elevation (m)
1:2 year	100.8	99.0
1:5 year	123.2	99.2
1:10 year	138.1	99.3
1:50 year	171.1	99.6
1:100 year	186.9	99.7

3.8.3 Hydraulic Assessment

We used a 1-dimensional hydraulic model (HEC-RAS) to estimate water velocities associated with various flow events. A detailed survey of the channel was not available, so estimates of the channel shape, dimensions and slope were made from a low-quality aerial photos, site photographs and river bank survey information.

For the purpose of the model, we estimated the channel to have the following average geometry:

- Channel slope = 0.1% (0.001 m/m);
- Channel bottom width = 48 m;
- Channel side slopes = 1H : 1V; and
- Thalweg of 1 m depth and 25 m width.

Based on this geometry and the Q2 = 100.8 m^3/s, our model predicted a water depth of 1.55 m and a water velocity of 1.36 m/s.

3.8.4 Drag Forces Acting on Boat

Tetra Tech EBA was also requested to estimate the maximum force exerted by the water on the boat. We considered the Q2 instantaneous peak flow in our analysis due to the fact the site would not be used during extreme flow events larger than Q2.

We employed a standard equation for drag to estimate the maximum force of water acting on the boat. The equation considers parameters including the water velocity, the maximum surface area exposed to the velocity, the viscosity of the fluid and a coefficient of drag for the object. We estimated that a maximum surface area of 1 m^2 would be exposed to the current. Based on these numbers, the load applied to the boat would be 1.83 kN.

3.8.5 Potential for Debris in Stream

Although Parks Canada has not reported or observed debris impacting the previous cable systems, it is noted that large woody debris is present in the Rabbitkettle River upstream of the ferryway, both in piles washed up on stream deposits and embedded in stream deposits. There are also several sections of trees along the shoreline that are overhanging the stream and should be expected to sometime fall into the stream (Photos 7 through 11, 15 and 16). The potential therefore exists for debris to flow along the river and impact the ferryway cable system, particularly during spring flood or storm runoff conditions.

4.0 PERFORMANCE OF EXISTING CABLE POSTS AND ANCHORS

Carswell (2010) reported on the condition of the existing cable posts and anchors. Carswell observed that the existing south post projected about 0.70 m further above grade than the north post, resulting in an elevation difference of about 1.11 m at the tops of the posts. The post holes were surmised by Carswell to have been about 250 to 300 mm in diameter, of unknown depth, and filled with concrete around the posts. The cable posts were noted to be leaning, with the north post leaning towards the river at about 141 mm out-of-plumb and the south post leaning to the north and east at about 340 mm out-of-plumb. Assuming that the original lengths of the posts were identical, Carswell's observations suggest that frozen soil may have been encountered while excavating the post holes, with frozen soil encountered at a shallower depth at the south post.

Duckbill anchors have been used at the site in the past. Carswell noted two Type 138 Duckbill anchors near the north cable post and two Type 138 Duckbill anchors near the south cable post, with two tree anchors supplementing the anchorage of the south post (Figure 3). As noted above, this anchor type has allowed significant movement in the cable posts of the previous iteration of the cable system, as well as apparent pulling-out of the anchors (Carswell, 2010). Given that the duckbills would have been driven into soils that may have been still seasonally frozen at the time of installation, this anchor type is not ideal, particularly as it is not possible to examine whether they have been damaged during installation. The fact that two tree anchors were needed at the south post strongly suggests that the duckbills could not be driven deep enough to achieve sufficient resistance.

5.0 RECOMMENDATIONS

5.1 General

The site is expected to be suitable for the proposed development, although there are some caveats associated with the various unknowns at the site. It is understood from Parks Canada that the existing ferryway and its predecessor have performed satisfactorily during their respective lifetimes, and they would like the replacement ferryway to consist of essentially the same system as the current system, with minor upgrades to cable and foundation capacities if/as needed. Tetra Tech EBA understands that Parks Canada desires to have a service life of at least 20 years for the replacement ferryway system, similar to or better than the service lives of the previous ferryway installations.

While Tetra Tech EBA would also recommend the consideration of alternatives to enhance the safety of the system, it is understood that Parks Canada is satisfied with the current system and is not prepared to spend additional funds for an alternative crossing concept. Therefore, we will provide recommendations that should allow satisfactory performance of the foundations under ordinary operating conditions.

The limitations and problems associated with the previous iterations of foundations and anchors have been noted, and alternatives have been developed to mitigate those issues in the new proposed foundations for the cable supports and the cable anchors. The detailed design for the cable supports and anchors has been developed in an iterative process with the structural engineering team and the Parks Canada operations and assets teams in order to optimize the design to accommodate operational conditions and satisfy regulatory guidelines and requirements as closely as possible. The remoteness of the project site, the low number of users, the overall success of previous ferryway operations at the site, and the operational limitations of the ferryway system were considered in the design of the system. The design was refined to suit the operational needs of Parks Canada, while incorporating provisions to improve operational safety and help protect Parks Canada's capital investment.

It is understood that, in order to satisfy operational requirements, Parks Canada accepts the risk of allowing a smaller minimum recommended freeboard (1.0 m instead of 1.5 m), as well as accepting the risks associated with the possibility that the minimum recommended freeboard of 1.0 m during either operations (estimated at Q2 or less) or spring flood or storm events (estimated up to Q100) may not always be satisfied (telephone and email discussions, May 23 through June 12, 2014: J.Reeves; R.Kors-Olthof, et al). In the event that high water levels, a capsized boat, and/or debris result in overloading of the cable system, a shear pin in the cable mounting apparatus is proposed in order to release the cable and protect the cable supports and anchors against overloading. Whether or not the boat is capsized (thus far never experienced), the release of either cable end should also allow the boat to drift to shore rather than being stuck at the middle of its trajectory.

Recommendations are provided below for cable foundations, anchors, and erosion protection for the north bank of the Rabbitkettle River. Consideration has been given to the remoteness of the site, hence reducing the weight of items needing to be imported and maximizing the use of materials readily available on site. Items for further consideration are also discussed, and recommendations for further work are presented.

5.2 Climate Change Considerations

The impacts of potential climate change should be considered in the design of the new structure. A procedure for screening the vulnerability of a development to climate change is outlined by the Canadian Standards Association (CSA, 2010).

The sensitivity of the site to climate change is governed by the characteristics of the permafrost at the site. The community is in an area of extensive, discontinuous permafrost, with average anticipated ground temperatures just below 0°C. Because the subsurface soils are largely of alluvial origin, but permafrost with possible ice-rich lenses or layers is potentially present on portions of the site, Tetra Tech EBA characterizes the site sensitivity to be "high."

Under a "high" green-house gas scenario, the mean annual air temperature is estimated to increase about 1.1 °C over the next 30 years. For the 20-year proposed design life, the mean annual air temperature would rise by a total of about 0.8 °C (CSA, 2010). If there is permafrost at the site, permafrost soils may be expected to begin thawing. The practical implication is that foundation settlement could occur. Furthermore, based on the review of available information, it is anticipated that the permafrost in the foundation layer may contain layers or lenses of soil that have excess ground ice due to silt content. Therefore, the consequences of permafrost thaw are considered to be potentially serious, and they are ordinarily characterized as “major” for structures supported by shallow foundations (above or within the permafrost), but “minor” for structures supported on the generally frost-stable granular soils beneath the silty soils which, at this site, have not been clearly delineated. The consequences are mitigated, however, by the fact that the ferryway structure is somewhat flexible in its design, because if the foundations and anchors settle, their movements can be compensated for by adjusting the tension of the cable structure. Such adjustments can be made on an annual or semi-annual basis or, for instance, at the start and finish of the visitor season. Therefore, the consequences of permafrost thaw are overall considered “minor” for this site.

Considering the site sensitivity and the associated consequences together results in a risk level “C” (low risk) as defined in CSA (2010), for a structure type that has been considered by Parks Canada to have been relatively successful in its two previous iterations at the project site. This level of risk warrants a qualitative analysis and the use of expert judgement to develop design parameters for a project with routine design parameters. This level of analysis and judgement has been employed to develop the recommendations for foundations and anchors provided in this report.

5.3 Site Preparation

5.3.1 General

The contractor will need to consider preparation of staging areas, the removal of existing site materials not being re-used at the site, and requirements for work areas within the ferryway footprint.

If the work is to be carried out by hand, then very little site preparation is likely to be required, but it should be recognized that the surficial soils, particularly the silty soils, may be prone to poor trafficability and ponding water. If some of the excavation work or installation is to be carried out by machine, then a work pad may need to be considered to limit the damage to the subgrade. Since granular material is not readily available, timber pads could be considered for use as work pads or in staging areas to protect the ground surface, and these could be readily removed again when the work is done.

Erosion protection work taking place directly adjacent to the stream may have to wait for lower river water levels, otherwise some sort of cofferdam construction may need to be considered. Similar considerations will apply if borrow material is to be acquired from the streambed gravel deposits.

5.3.2 Stockpiling of Excavated Materials for Later Use

Separate areas should be designated on both sides of the river for stockpiling of materials that are to be excavated from the footing and anchor sites, and reserved for use later in the construction process. Excavated materials to be reused include the peat/vegetation/organic layers, which are to be placed on top of finished footing sites and anchors, and sandy/silty soils which will be used as general engineered fill over footings and within the SierraSlope gravity anchors. If the peat/vegetation/organic layers can be preserved in relatively intact sections or strips, this will save some labour when they are put back into place later.

5.4 Location of North Cable Post

As the north river bank is prone to erosion and the river has made a significant cut into the bank at the ferryway location, the first line of defence should be to set the north cable post further back, away from the shoreline. While it may be possible to mitigate erosion with the use of erosion protection (further discussed under “Erosion Protection” below), it is considered prudent to increase the setback distance from the river. An additional setback of at least 5 m behind the existing post is recommended, located as shown in Drawing S0001.

5.5 Erosion Protection

Since the north bank of the Rabbitkettle River has been subject to scour from the river, resulting in an overhanging river bank, it is recommended that Parks Canada protect the north river bank, thereby protecting the north cable support structures and providing easier access to the boat at this steep location. Figure 4 provides a concept for a timber crib structure to protect the bank. The concept can be fine-tuned once it is known whether materials on site (trees) can be used in the structure or whether construction materials need to be imported. The purpose of the timber cribs is to reduce the likelihood of further retrogression of the river bank due to river scour, and prevent the boat from bumping up against the river bank while at anchor, which appears also to have been an active force in erosion.

Some excavation into the toe of the river bank and into the slope will be required in order to install the timber cribs and the tiebacks. This work would preferably take place late in the construction season, when the ground is still thawed, but the river level is at or close to its seasonal low. Further discussion of construction excavations, as well as backfill materials and compaction, are provided below.

Some consideration is required to limit potential scour at the toe of the timber cribs. The granular material available on site is not well suited for riprap. The largest material encountered (about 125 mm diameter) was seen in the gravel beds in the river. Since the river has moved this material, it is too small for use in riprap. Therefore, the timber cribs should either be dug in deeper or, ideally, some form of man-made riprap should be provided. One possible alternative would be to fill sand bags with local sandy soils mixed with imported bagged cement. Once hydrated, the sand-cement bags would be stacked in a wedge at the toe of the timber cribs to form a layer of riprap.

Tetra Tech EBA provided a proposal on May 2, 2014 to Parks Canada for the detailed design of erosion protection on the north shore. It is understood that Parks Canada will not proceed with the design and installation of erosion protection at this time. Therefore, it is important that the new north post be protected by placing it further from the existing river bank than its current location, as discussed above under “Location of North Cable Post.”

5.6 Cable Support Post Footings

A-frames are proposed to support the ferryway cable, replacing the existing posts. The A-frames are intended to allow some variation in loading direction due to changes in the sag of the cable due to the load from the boat while crossing the Rabbitkettle River, as well as changes in loading direction due to variations in stream velocity. The legs of the A-frames are to be supported on W200x22 by 1220 mm long beams, which in turn are supported on C200x17 by 1220 mm long channel sections, as shown in Detail 2 of Drawing S0002.

The footings are anticipated to be lightly-loaded, to an anticipated maximum of about 10 kN or 7 kPa, and will be founded at 0.6 m below ground surface, as shown in Details 3 and 4 of Drawing S0002. According to the findings from the site investigations carried out by Sabatini (2010) and recently by Tetra Tech EBA, the footings will be founded on silty sand or sandy silt soils, within the active layer. Depending on when the footing areas are excavated, the proposed footing depth may be very close to the thaw depth of seasonal frost. The later in the season that excavation takes place, the less likely that the excavation work will be impeded by seasonal frost.

The surficial peat/vegetation/organic layer should be removed from the footing areas and stockpiled for later use. The underlying soils can be excavated and placed in a separate stockpile for re-use as backfill over the footings, if deemed suitable for use as general engineered fill. The footings should be placed on undisturbed, unfrozen native soils. The channel sections forming the base of the footings should allow the footings to be pressed into the unfrozen soil bearing surface, such that the soil will uniformly support the footings.

From the tops of the footings, up to 150 mm below ground surface, the backfill soil should be compacted in lifts of 100 mm maximum thickness, to 95% of Standard Proctor maximum dry density. The upper 150 mm of the fill should be lightly compacted to 90% of Standard Proctor maximum dry density, as for landscape fill. The lower density will allow vegetation to re-establish while mitigating excessive settlement in the landscape fill soils. The stockpiled peat/vegetation/organic layer can then be replaced on the ground surface and lightly tamped into place.

Additional recommendations for shallow foundations are provided in Appendix C, Design and Construction Guidelines. The section Backfill Materials and Compaction below provides additional information on general engineered fill.

5.7 SierraSlope Gravity Anchor with Geogrid Resistance Frame

A simple SierraSlope soil-retaining concept is proposed to reduce the requirements for importing heavy items to site, to eliminate the need to make concrete on site (and eliminate the search for suitable concrete aggregate and the acquisition of that aggregate), and to allow maximum use of the materials on site. Metal frames supporting geogrid panels beneath the SierraSlope soil mounds will anchor the rods leading from the A-frame cable supports, and serve as resistance to both sliding and uplift forces due to the ferryway cable loads. The anchor structures will be located as shown on Drawing S0001, and designed as shown in Drawing S0002, Details 1 and 3.

If the project is to be completed by Autumn 2014, the construction team will likely need to start relatively early in the construction season in order that foundations and anchors can be built, and the cables installed and tested before the end of the season. Because the ground will be thawing all summer, the ideal time to excavate soils at the site would be late in the season – late August to early September. However, the construction team may not be able to take full advantage of this thawing trend, and may need to implement other strategies to excavate holes for foundations and anchors. Further discussion is provided below under “Construction Excavations.” Soils on the south side of the river are likely to stay frozen longer than the north side, due to shading from the slope south of the crossing site.

The anchor frames are proposed to be placed at a depth of about 0.6 m below ground surface, as shown in Drawing S002, Detail 3. The SierraSlope soil-retaining structures would be founded at about 0.1 m below ground surface, just below the anticipated organic soils, and would be constructed in two layers, with facings, support struts, geogrids, and geofabrics installed as per the manufacturer’s recommendations. The structures would ideally be backfilled with the same materials that are excavated from the holes, if they are deemed suitable for use as general engineered fill, as discussed further in the section Backfill Materials and Compaction below. It is recognized that these materials may incorporate silty soils, so sourcing of alternative materials may need to be considered on site when the soils are inspected. As well, some borrow material will be required to complete the structures. A small amount of material may be available from the footing excavations, but most of the additional material will need to be imported from offsite, as further discussed in Backfill Materials and Compaction.

From the base of the excavation at the geogrid frame structure, up to 150 mm below the top of the fill, the backfill soil should be compacted in lifts of 100 mm maximum thickness, to 95% of Standard Proctor maximum dry density, as noted on Drawing S0002. The upper 150 mm of the fill, as well as the topsoil inserts in the faces of the SierraSlope structure, should be lightly compacted to 90% of Standard Proctor maximum dry density, as for landscape fill. The lower density will allow vegetation to re-establish while mitigating excessive settlement in the landscape fill soils. The upper surface of the fill on top of the SierraSlope structures should be sloped at minimum of 2% from the centre out to the edges to maintain positive surface drainage. The stockpiled peat/vegetation/organic layer can then be replaced on the ground surface and lightly tamped into place.

Further recommendations and instructions for the design and construction of SierraSlope structures are provided in Appendix D.

5.8 Seismic Hazard

The National Building Code of Canada provides a seismic hazard calculator for the estimation of seismic hazard across Canada, according to the 2010 standards. Table 4.8-1 below provides the interpolated seismic hazard values for a 2% probability in 50 years.

Table 4.8-1: National Building Code Interpolated Seismic Hazard Values

Sa (0.2)	Sa (0.5)	Sa (1.0)	Sa (2.0)	PGA
0.511 g	0.314 g	0.158 g	0.088 g	0.245 g

These values indicate a significant seismic hazard that may need to be considered in the design.

5.9 Construction Excavations

The Government of the Northwest Territories Safety Act and Regulations and standard good practice should be followed for all trenches/excavations. Excavations deeper than 1.5 m should have sloped sidewalls. A slope of 1 horizontal to 1 vertical (1H:1V) is the steepest recommended slope for temporary excavations in these soils. Localized instability (seepage/sloughing/flowing soil) in trench/excavation walls may occur. In these cases, side slopes would need to be made flatter, under the direction of a qualified geotechnical engineer.

Assuming that the site surface is reasonably dry at the time of construction, seepage into shallow excavations at the tops of the river banks (foundation and anchor locations) should be minimal based on observations from the previous site investigations, as long as the river water level is relatively low and excavations are not left open too long. However, the contractor should be ready to dewater the excavation if necessary, since seepage may be present seasonally. If seepage is encountered, pumps should be sufficient for drainage of seepage.

At the proposed timber crib location at the north access to the ferryway, the river level should be allowed to drop to near its lowest level before attempting to excavate into the toe of the river bank, as both seepage and sloughing are likely, and difficulties in construction are more likely at higher water levels. Due to the granular nature of the soils at the toe of the river bank, some alternative means of keeping the water out of the excavation may need to be considered by the contractor.

The near-surface soils encountered at the site are likely to be easily excavated when thawed, and drier granular soils may also be readily excavated by machine or by hand. However, frozen soils that are damp or moist are likely to be well-bonded and therefore difficult to excavate. Because construction will commence before the seasonal frost is out of the ground, provisions will need to be made for difficult excavation conditions. Tetra Tech EBA had some success in excavating shallow test holes with a hand-held rock hammer drill, so similar solutions on a larger scale may be suitable for construction. Possible solutions could include hand-held jackhammers to break up the soil so that it can then be excavated with shovels. A small Kubota equipped with a jackhammer and excavator bucket could be mobilized to CanTung and then flown to site. This option would be more expensive to mobilize and to move on site, but could save some time during construction.

General guidelines with respect to excavations are presented in Appendix B.

5.10 Backfill Materials and Compaction

Frost-stable granular materials are preferred for backfilling around foundation or anchor locations as described above; however, the proposed structures are relatively tolerant of movements, and the anticipated sands and silts could be used as general engineered fill, if deemed acceptable upon excavation. Sands or silts could also be used as bedding materials or in site grading, with specific suitable uses to be determined upon inspection. Borrow materials could include soils borrowed from the gravel beds in the river, the beach areas at the ferryway, or possibly from the glaciofluvial deposit downstream of the ferryway on the north bank. However, such materials would need to be further investigated and available quantities and qualities of materials proved. An environmental impact assessment is also likely to be required for the use of local materials borrowed from offsite.

- Sands and silts at the footings and/or anchors. It is anticipated that the same soils removed from the excavations could be used to backfill the excavations and build up the SierraSlope soil-retaining structures. This material generally contains more than 10% fines and is considered to be somewhat to highly frost-susceptible depending on the proportion of silt. Therefore, this soil type should not be used for backfill where seasonal frost heave cannot be tolerated. However, it could also be suitable for site grading in areas not requiring frost-stable fill. Depending on material characteristics, it may need erosion protection if placed in an area that will receive surface water runoff. The typical moisture contents observed by Tetra Tech EBA in the silt and sand materials suggest that this material is likely to need drying in order to achieve optimum moisture content.
- "Beach" sand, similar to the surficial layers at the subject site. This material could be suitable for site grading or bedding materials. The content of gravel and fines varies in this material, so its proposed use should be adjusted accordingly, since it may be highly erodible if it has little gravel or fines, or too coarse for bedding if it has too much gravel or the gravel is too coarse (exceeding 10 mm in size). Sources with no more than 10% fines (silt and clay-sized particles) could be suitable for bedding or site grading that requires frost-stable soils. Sources with less than about 3% fines, however, may be too easily disturbed to be suitable for travel surfaces. If used for bedding, the material may need to be screened for this purpose. The moisture content of this soil type varies widely from moist to wet to very wet. Depending on the characteristics of the borrow source, it may need either wetting or drying to bring it to within +/-1% of optimum moisture content.
- In-stream "gravel" deposits. This material likely varies in composition from sands to gravels to cobbles. Based on the site investigation, a maximum size of about 125 mm is anticipated. Like the beach sand discussed above, the proposed use of the material will depend on the gradation of the material excavated, although finer materials could be blended with coarser materials, or the coarsest materials screened out. Wetting or drying may be required to bring the material to within +/-1% of optimum moisture content.

When compacting the silty soils, the materials should be uniformly moisture-conditioned to within +/- 2% of optimum moisture content, if/as needed. If the material is too wet, it will tend to pump and have poor trafficability, and the required soil density (degree of compaction) may not be achieved. If the material is too dry, the required soil density may be achieved, but the material will be subject to settling when it absorbs water after construction. Granular soils should be similarly moisture-conditioned to within +/- 1% of optimum moisture content.

5.11 Site Grading and Drainage

It is recommended that final site grading be provided to direct water away from the foundation and anchor structures. Improper drainage and ponding of water near or under the structure could initiate foundation or anchor failure. The overall natural drainage is towards the Rabbitkettle River on both sides of the ferryway, but the 2010 Parks Canada site survey indicates that the north side of the river is much flatter than the south. Therefore, more care will be needed to prevent the ponding of water on the north side.

Generally, Tetra Tech EBA recommends that final grade within 3 m of structures are sloped down, away from the structure at 4 %. It is also recommended that landscaped areas beyond 3 m from the structure should have a minimum grade of 2 %. In the present case, it is also desirable to reduce overall site disturbance; therefore, final site grading should take into account the presence of existing trees and shrubs, with the primary goal to maintain positive surface water drainage towards the river.

5.12 Concrete / Cement Type

One soil sample from near the north cable post was tested for water soluble sulphate content, with a result of 0.28%, indicating that the potential degree of sulphate attack should be categorized as "severe." Accordingly, the use of Type HS (formerly known as Type 50) Portland cement at a maximum water/cementing material ratio by mass of 0.45 and a minimum specified 56-day compressive strength of 32 MPa is expected to be appropriate.

Stricter recommendations for concrete strength and durability may be required due to structural considerations.

Assuming a maximum coarse aggregate size of 14 - 20 mm, air entrainment of 5 to 8 % is recommended for all concrete exposed to freezing temperatures, native soils, and or groundwater. If imported fill is placed in contact with concrete, that fill should be tested for water soluble sulphate content, and the above recommendation re-evaluated.

6.0 DESIGN AND CONSTRUCTION GUIDELINES

Recommended general design and construction guidelines are provided in Appendix C, and include the following:

- Construction Excavations (1 page)
- Backfill Materials and Compaction (4 pages)
- Shallow Foundations (1 page)

These guidelines are generic and are intended to present standards of good practice. They have been developed largely from Tetra Tech EBA's southern practice. However, we have attempted to address specific local requirements in the main text of this report. In the event of any discrepancy between the main text of this report and the appendices, the main text should govern.

7.0 REVIEW OF DESIGN AND CONSTRUCTION

Tetra Tech EBA should be given the opportunity to review details of the design and specifications related to geotechnical aspects of this project prior to construction.

All recommendations presented in this report are based on the assumption that an adequate level of monitoring will be provided during construction, and that all construction will be carried out by suitably qualified contractors, experienced in earthworks and foundation construction in the north. Adequate levels of construction monitoring for foundations are considered to be full time monitoring by a qualified geotechnical engineer or technologist during construction and design review during construction. Monitoring activities should include the following:

- Review of design drawings and specifications prior to construction;
- Observation of site prior to commencing site preparation work;
- Observation of all bearing surfaces prior to placement of bin walls;
- Inspection and laboratory testing of engineered fill to ensure that it meets the necessary gradation and is in an appropriate state for compaction;

- Full-time monitoring and quality assurance during earthworks; and
- Provision of recommendations if unforeseen circumstances arise.

All such quality assurance monitoring should be carried out by suitably qualified persons, on behalf of the owner, independent of the contractor. If the contractor also uses quality assurance for quality control, all parties should be made aware of this. One of the purposes of providing an adequate level of monitoring is to check that the provided recommendations, which are based on a review of available information and limited site investigation, are valid. It should be noted that failure to provide an adequate level of foundation monitoring may contravene Building Code Requirements.

8.0 PERFORMANCE MONITORING

The performance of foundations, anchors and erosion protection structures should be checked by Parks Canada staff on at least an annual basis, for instance, at the beginning of each season of use. Additional inspections should be considered after major precipitation events and/or flooding events.

Should observations be made that indicate possible changes in the performance of the structures, including movement of the soils around the foundations and anchors, or loosening of the rods and cables that suggests such movement may be occurring; Tetra Tech EBA should be advised. Similarly, if continued erosion or scouring is observed, we should be advised. Because this is such a remote site, regular inspections will be valuable in detecting changed conditions that may require future maintenance or repairs on a timely basis.

REFERENCES

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Sabatini Earth Technologies Inc., 2010. Geotechnical Investigation, Proposed Cable Car Crossing, Rabbitkettle River, Nahanni National Park Reserve, Northwest Territories, Prepared for Parks Canada c/o Carswell Consulting Engineers Ltd. July 2010.

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9.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

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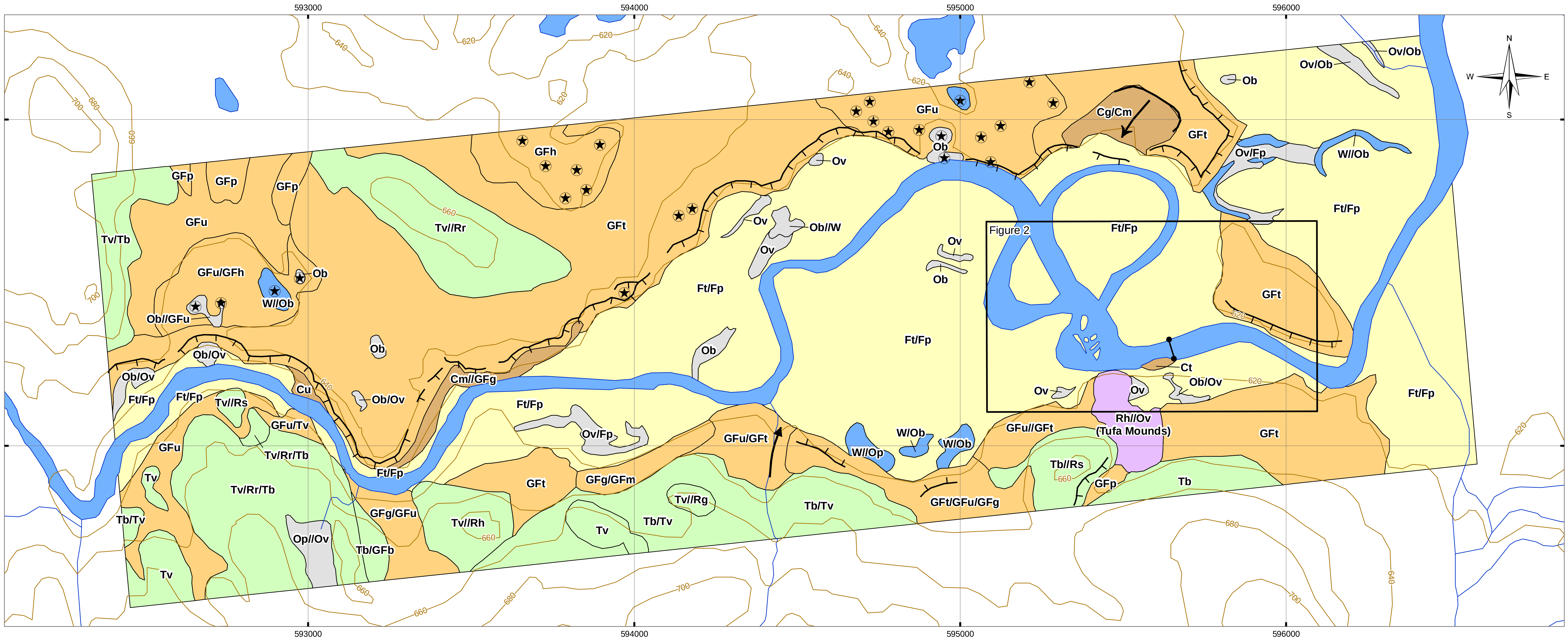
PERMIT TO PRACTICE
TETRA TECH EBA INC.
Signature
Date June 26/14
PERMIT NUMBER: P 018
NT/NU Association of Professional
Engineers and Geoscientists

FIGURES



LEGEND

- Kettle
- Gully
- Landslide and active layer failure scar (large)
- Escarpment
- Ferryway Cable Structure
- Contour (20 m)
- Stream
- Waterbody

SURFICIAL MATERIAL

T **Till:** very poorly sorted sediment (diamicton) deposited directly by ice by lodgment, melt out, or post-melt out gravity flow; generally matrix-supported and compact. Clasts may comprise subangular to very angular pebble, cobble and boulder gravel, and the till may have a clay to granule gravel matrix. May contain lenses or beds of better sorted material deposited within subglacial or supraglacial channels, or of deposits pre-dating the last glaciation. Generally found as blankets and veneers over bedrock.

GF **Glaciofluvial Deposit:** well to poorly sorted sediment deposited by glacial meltwater rivers (subaerial or outwash deposits). Consists of sand near project site, but may contain gravel elsewhere. Includes material deposited in proglacial lakes in contact with glacier ice (ice-contact deposits, deltas and subaqueous fans) and material deposited at the margins of glaciers (kames). Glaciofluvial sediments are generally massive or vaguely horizontally bedded. Kettles and faults formed by ice melt beneath the deposits are common. Larger outwash deposits have formed terraces due to downcutting during deglaciation.

SURFICIAL MATERIAL

F **Fluvial Deposit:** sediment deposited by modern rivers and small streams in channels or as point bar or overbank deposits (synonymous with alluvial deposit). Moderately to well sorted sand and silt, with some gravel, and minor clay. Clasts are subrounded to well rounded.

C **Colluvial Deposit:** poorly sorted, commonly poorly compacted material, deposited by gravity-induced slumping. May include bedrock and/or glaciofluvial sediments.

O **Organic Deposit:** woody, fibrous peat, present in wetlands (bogs and fens) and organic mud; underlain by poorly drained sediment or bedrock. Forms veneers, blankets and plains and is commonly found within abandoned fluvial channels.

R **Bedrock:** sedimentary rocks of Ordovician, Silurian and Lower Devonian age: shale, chert, siltstone, sandstone, limestone and dolomite; and tufa of Holocene age that continues to form.

W **Water:** water bodies such as lakes and rivers and open water areas within wetlands.

SURFICIAL EXPRESSION

b **Blanket:** deposit greater than 1 m thick; minor irregularities of the underlying unit (generally bedrock) are masked but the topographic form is still evident.

v **Veneer:** deposit less than 1 m thick; minor irregularities of the underlying unit (generally bedrock) are masked but the topographic form is obvious.

p **Plain:** flat or relatively level landscape element; bedrock topography is masked.

t **Terrace:** level or gently inclined surface flanked by a steep slope or scarp; bedrock topography is masked.

h **Hummocky:** random assemblage of mounds and depressions with no trend or parallelism; bedrock topography is masked.

u **Undulating:** low relief, rolling terrain with no trend or parallelism; bedrock topography is masked.

r **Ridge:** narrow, elongate and commonly steep-sided feature that rises above surrounding landscape; bedrock topography is masked (unless a bedrock ridge).

g **Gentle slope:** feature forms a slope of 5-15°.

m **Moderate slope:** feature forms a slope of 16-35°.

s **Steep slope:** feature forms a slope of more than 35°.

DELIMITERS

/ First component more common than second (e.g. Tv/Ov means till veneer covers 60-75% of polygon area, and organic veneer covers the rest).

// First component much more common than second (e.g. Tbv//Rr means that a combination of till blanket and till veneer cover 80-95% of polygon area, with ridged bedrock covering the rest).

- First component approximately equal in proportion to the second.

TERRAIN CODE

Fp//Ov

First unit — Delimiter — Second unit

Upper case letter = Surficial Material
Lower case letter = Surficial Expression

NOTES

1. Base data source: CanVec.
2. Terrain mapping based on aerial photos A24543-216 and 217,and on subaerial photos from helicopter 2014-02-07 and 2014-03-04.

STATUS
ISSUED FOR USE

REPLACEMENT OF RABBITKETTLE RIVER FERRYWAY
NAHANNI NATIONAL PARK RESERVE, NT

Site Location and Terrain Map

PROJECTION	DATUM	CLIENT
UTM Zone 9	NAD83	Parks Canada / Parcs Canada

Scale: 1:12,000
200 100 0 200
Metres

FILE NO.
Y14103255-01_001_Figure01_Terrain.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103255-01	SL	MEZ	SMC	0

OFFICE	DATE
Tt EBA-VANC	June 25, 2014

Figure 1

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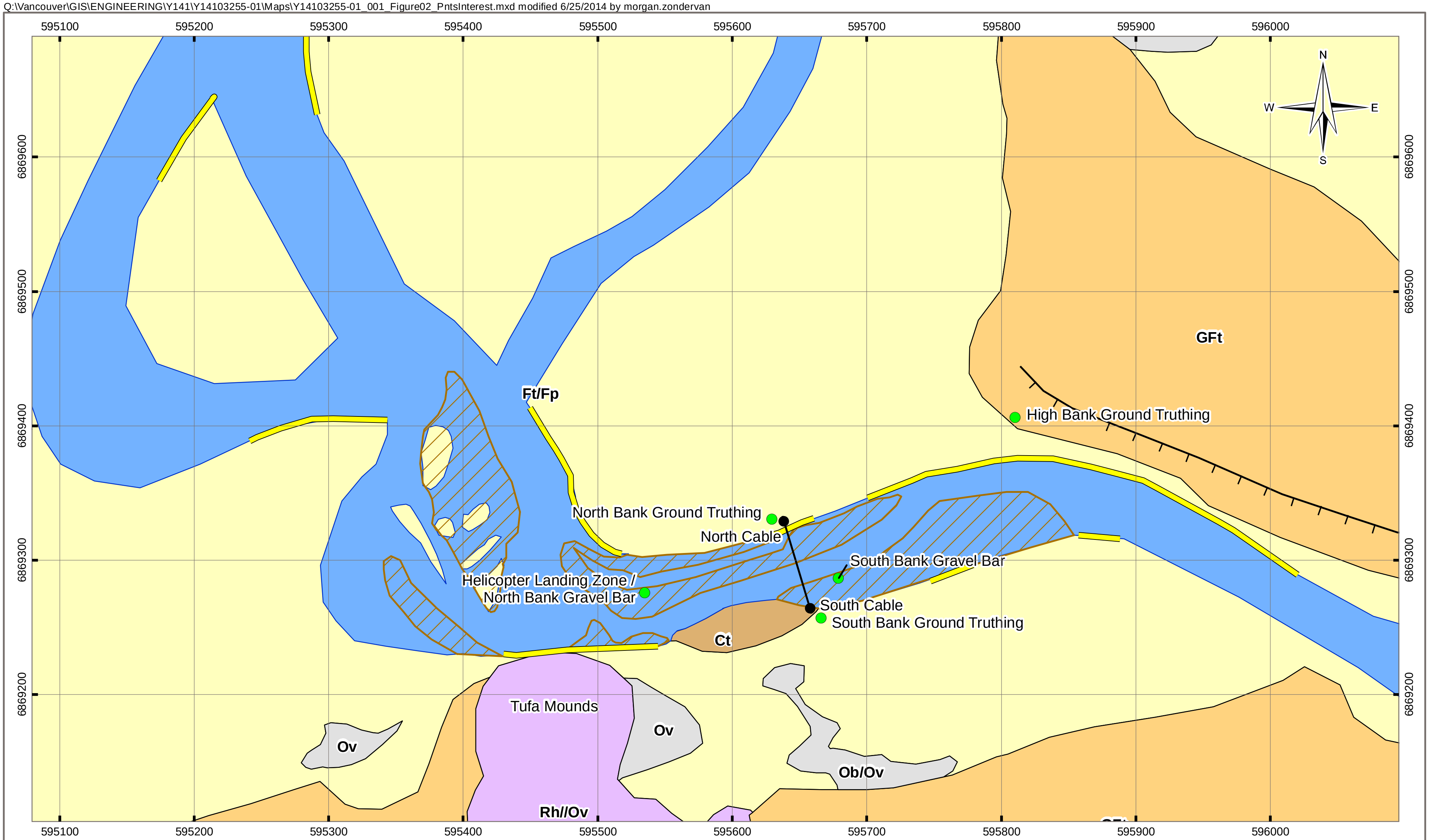


LEGEND

- Observation Point
- Ferryway Cable Structure
- River Bank Erosion
- Areas of Deposition (including gravel bars)

Surficial Geology

- Organic
- Colluvial
- Fluvial
- Glaciofluvial
- Till
- Bedrock
- Water
- Escarpment

NOTES
Base data source: CanVec
See Figure 1 for detailed geology legend

Scale: 1:4,000
50 25 0 50
Metres

STATUS
ISSUED FOR USE

PROJECTION	DATUM
UTM Zone 9	NAD83

FILE NO.
Y14103255-01_001_Figure02_PntsInterest.mxd

CLIENT
Parks Canada Parcs Canada
TETRA TECH EBA

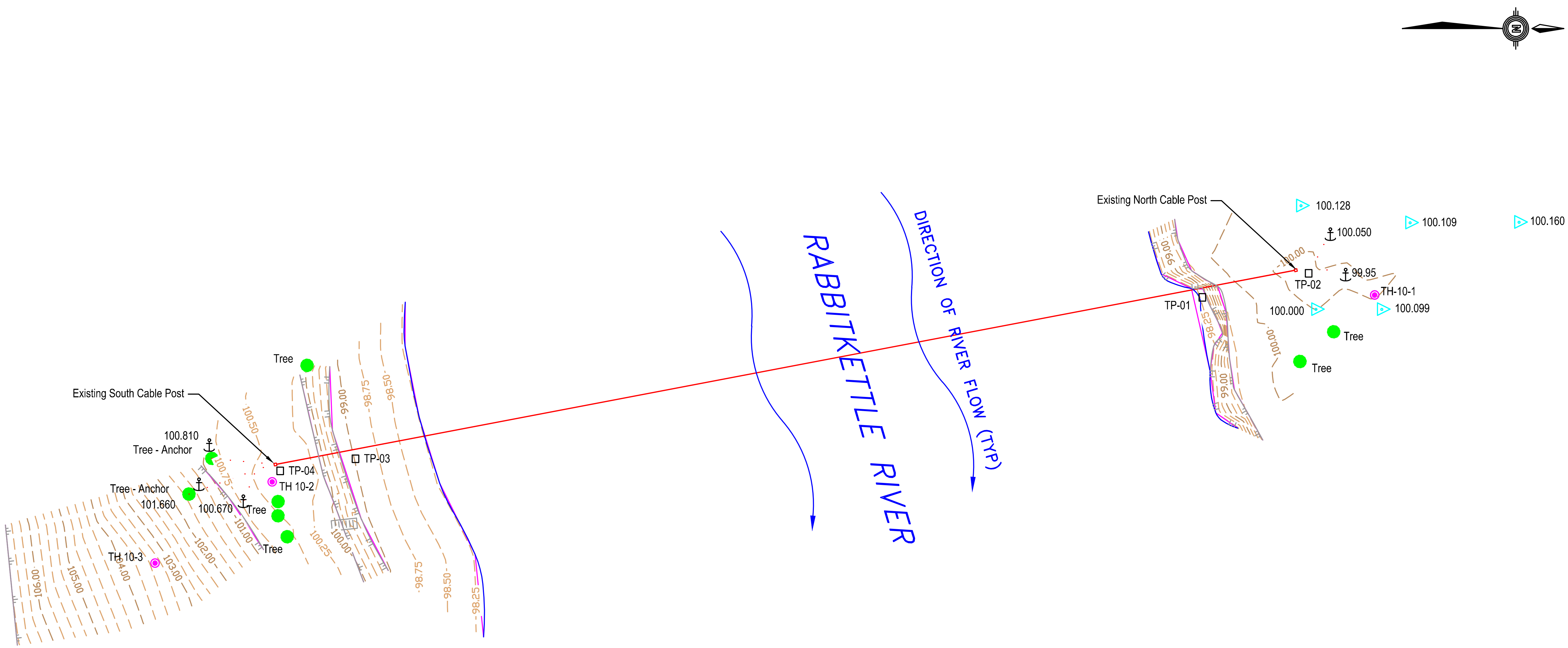
REPLACEMENT OF RABBITKETTLE RIVER FERRYWAY NAHANNI NATIONAL PARK RESERVE, NT

Local Geological and Hydrotechnical Site Features

PROJECT NO.	DWN	CKD	APVD	REV
Y14103255-01	MEZ	SL	TS	0

OFFICE	DATE
Tt EBA-VANC	June 25, 2014

Figure 2



ISSUED FOR USE

LEGEND

- Hand-augered boreholes - Sabatini (2010)
- Test pit - Tetra Tech EBA (2014)

0 10m

Scale: 1:250 @ 11"x17"

NOTE

- BASE PLAN PROVIDED BY PARKS CANADA.

CLIENT

Parks Canada Parcs Canada

TETRA TECH EBA

REPLACEMENT OF RABBITKETTLE RIVER FERRYWAY
NAHANNI NATIONAL PARK RESERVE, NT

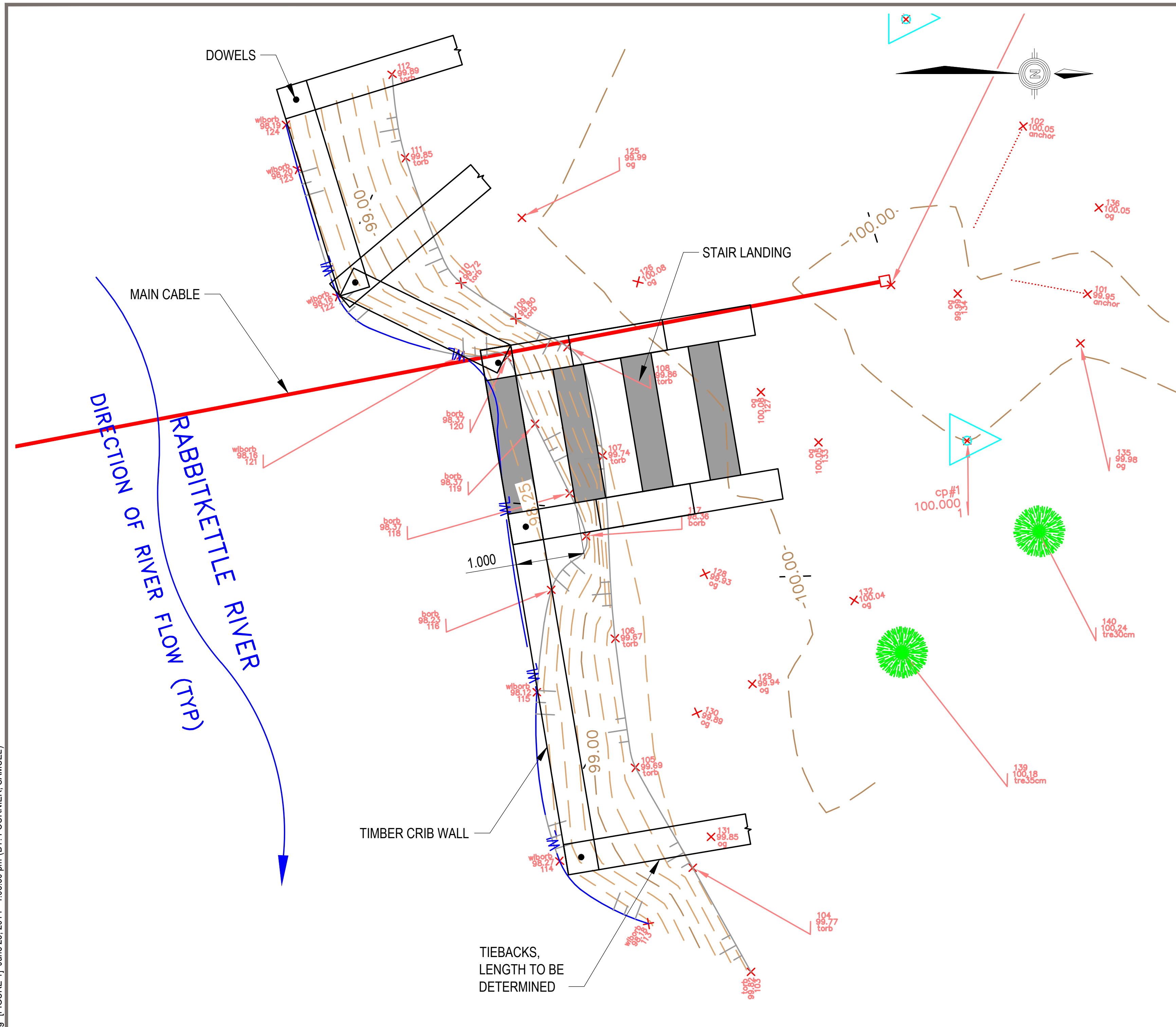
SITE PLAN

PROJECT NO.	DWN	CKD	REV
Y14103255-01	BR/MM	RKO	0

OFFICE	DATE
EDM	June 25, 2014

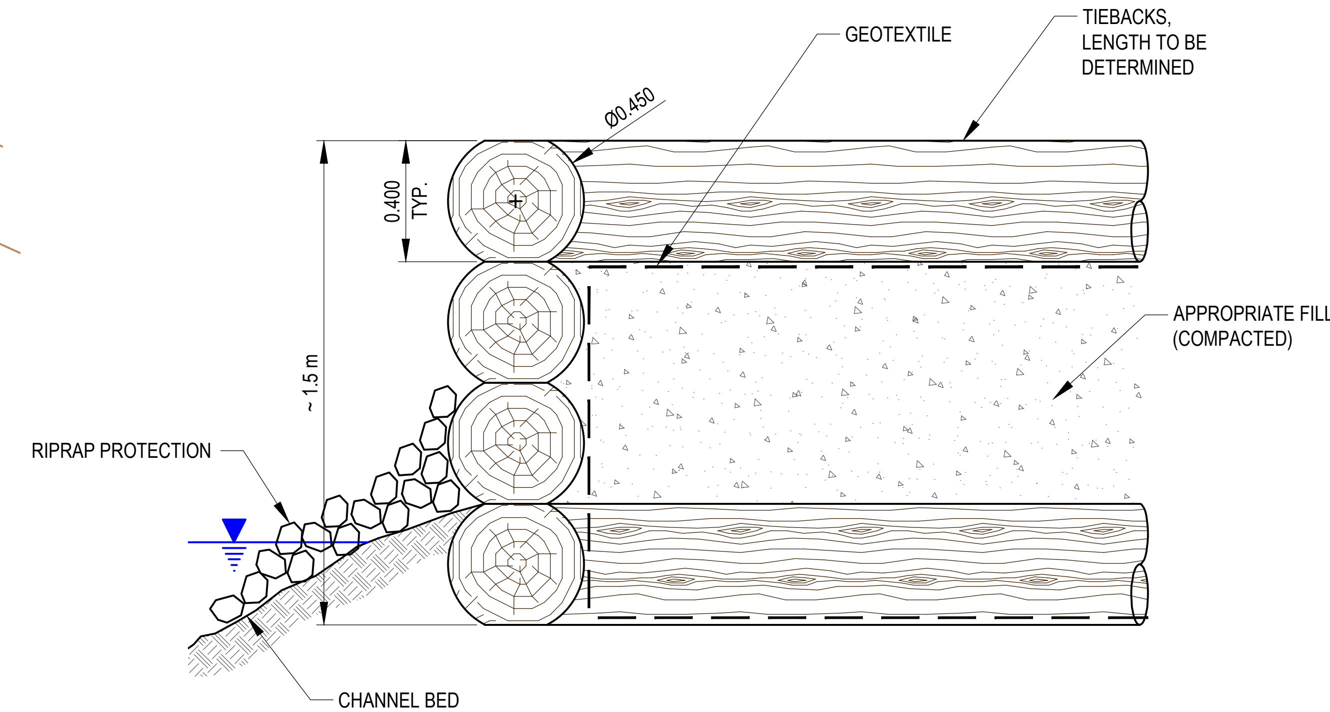
Figure 3

Q:\Vancouver\Drafting\Engineering\Y141\Y14103255-01\Y14103255-01_FIG 3_R0.dwg [FIGURE 3] June 25, 2014 - 1:07:19 pm (BY: FOURNIER, SAMUEL)



PLAN VIEW

SCALE 1:75



TYPICAL SECTION

SCALE 1:25

ISSUED FOR USE

NOTES
- BASE PLAN PROVIDED BY CLIENT.
- UNITS SHOWN ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.

CLIENT

Parks Canada Parcs Canada

TETRA TECH EBA

REPLACEMENT OF RABBITKETTLE RIVER FERRYWAY
NAHANNI NATIONAL PARK RESERVE, NT

PLAN VIEW AND TYPICAL SECTION OF TIMBER CRIB

PROJECT NO.	DWN	CKD	REV
Y14103255-01	SF	DJ	0
OFFICE	DATE		
VANC	June 25, 2014		

Figure 4

Q:\Vancouver\Drafting\Engineering\Y141\Y14103255-01\Y14103255-01_FIG 4_R0.dwg [FIGURE 4] June 25, 2014 - 1:05:50 pm (BY: FOURNIER, SAMUEL)

PHOTOGRAPHS

Photo 1	North bank gravel bar, upriver of ferryway structure. Aggregates up to 125 mm.
Photo 2	South bank gravel bar, downriver of the ferryway structure. Aggregates up to 75 mm.
Photo 3	South bank beach underneath ferryway cable. Soil is fine SAND.
Photo 4	North bank erosion underneath ferryway cable.
Photo 5	Closeup of scour zone on the north bank.
Photo 6	Overview of the north bank and the ferryway structure with the scour zone.
Photo 7	Overview of the Rabbitkettle River looking downstream (east).
Photo 8	Overview of the Rabbitkettle River looking upstream (west).
Photo 9	View looking west upstream. Note the trees slumping into the river.
Photo 10	View looking east downstream at area mapped as colluvial terrace.
Photo 11	View looking west up river from the slump zone on the south bank.
Photo 12	Frozen water seepage on the south bank, just up river of the ferryway site.
Photo 13	Steep glaciofluvial terrace slope on north bank of river downstream of ferryway.
Photo 14	SAND, silty, surface organics, brown to grey, damp; fine sand.
Photo 15	Looking downstream at piles of large woody debris along stream deposits.
Photo 16	Looking downstream at woody debris piled on leading edges of stream deposits.

Photo 1: North bank gravel bar, upriver of ferryway structure. Aggregates up to 125 mm in diameter.
Photo Taken March 4, 2014

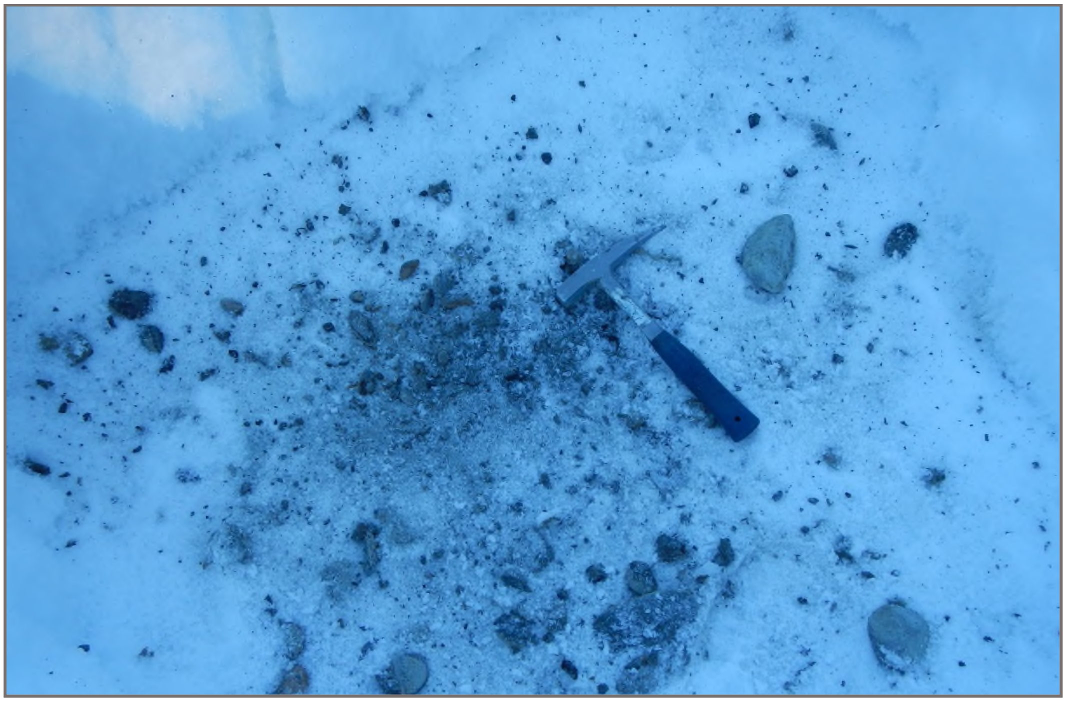


Photo 2: South bank gravel bar, downriver of the ferryway structure. Aggregates up to 75 mm in diameter. Gravel frozen and hard to break apart due to seasonal frost.
Photo Taken March 4, 2014

Photo 3: South bank beach underneath ferryway cable. Soil is fine SAND, with some silt, dry near the surface and frozen/hard just below.
Photo Taken March 4, 2014

Photo 4: North bank erosion underneath ferryway cable. Test drilling within the scour zone showed sandy soils and a gravel interbed. The scour has resulted in a 0.9 overhang.
Photo Taken March 4, 2014

Photo 5: Closeup of scour zone on the north bank. By the hammer head, the soil becomes rounded gravel and sand. The fragments are frozen chunks of sand.
Photo Taken March 4, 2014

Photo 6: Overview of the north bank and the ferryway structure with the scour zone visible below. The top of bank is about 1.8 m above the ice. The scour is confined to this photo.
Photo Taken March 4, 2014

Photo 7: Overview of the Rabbitkettle River looking downstream (east). The ferryway is marked by the red line. The location of the two main gravel bars is visible by deeper snow.
Photo Taken March 4. 2014

Photo 8: Overview of the Rabbitkettle River looking upstream (west). The ferryway is marked by the red line.
Photo Taken March 4, 2014

Photo 9: View looking west upstream. Note the trees slumping into the river at a location on the outside of the meandering river channel. Tufa mounds in background.
Photo Taken from Helicopter landing site, March 4, 2014

Photo 10: View looking east downstream at area mapped as colluvial terrace on south bank. The trees on the right side of the photo are just upriver of the ferryway structure where the hillside appears to be gradually slumping or subsiding into the river.
Photo Taken from Helicopter landing site, March 4, 2014

Photo 11: View looking west up river from the slump zone on the south bank. The helicopter is on the north bank gravel bar.
Photo taken March 4, 2014

Photo 12: Frozen water seepage on the south bank, just up river of the ferryway site. Likely the result of a high water table near the tufa mound springs.
Photo taken March 4, 2014

Photo 13: Steep glaciofluvial terrace slope on north bank of river downstream of ferryway (see also oblique aerial view in Photo 7).
Photo Taken March 4, 2014

Photo 14: SAND, silty, surface organics, brown to grey, damp; fine sand. Large trees present on portions of this slope, up to 30 cm diameter.
Photo Taken March 4, 2014

Photo 15: Looking downstream at piles of large woody debris along stream deposits about 0.6 km upstream of ferryway location.
Photo Credit: Parks Canada, February 7, 2014

Photo 16: Looking downstream at woody debris piled on leading edges of stream deposits and embedded in stream deposits about 0.2 km upstream of ferryway.
Photo Credit: Parks Canada, Feb 7, 2014

APPENDIX A
TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

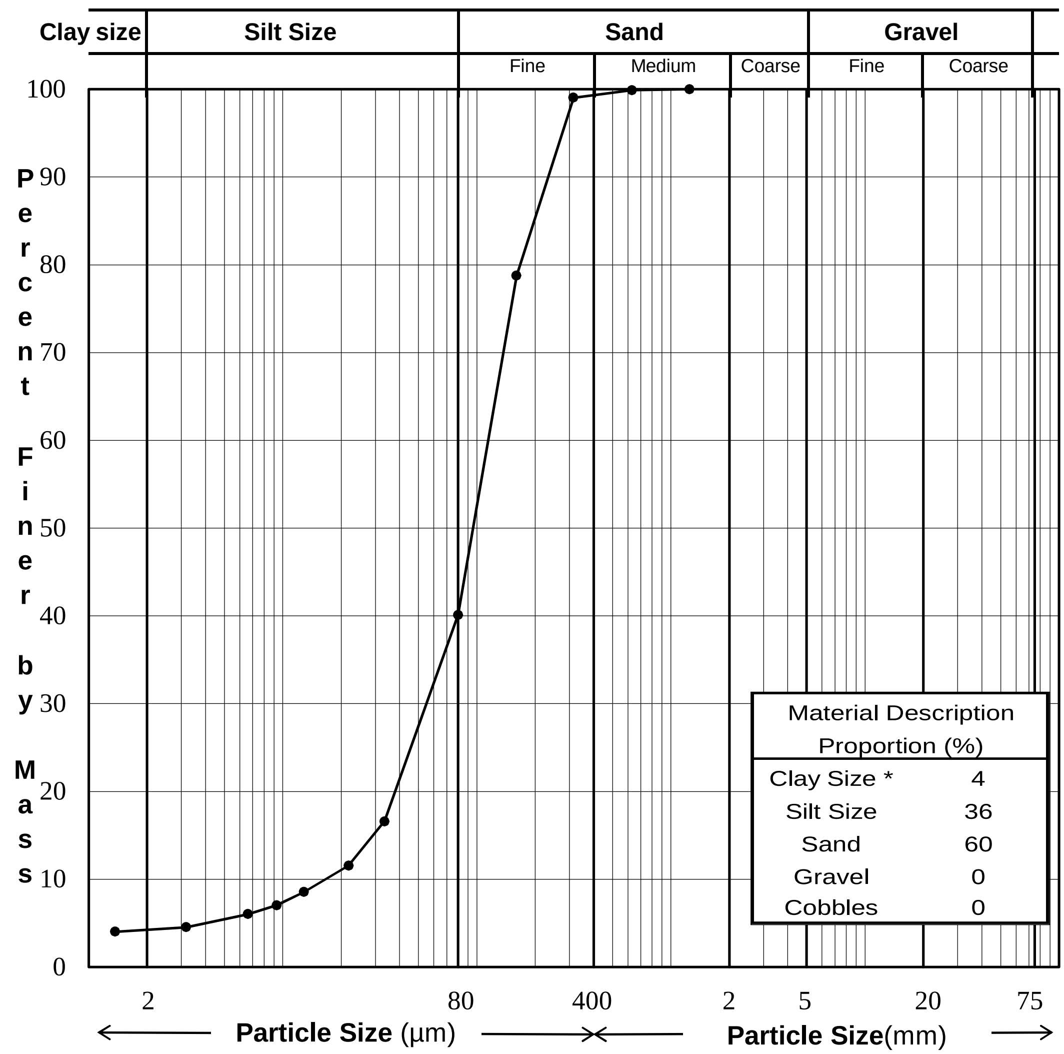
APPENDIX B
LABORATORY TEST RESULTS

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Rabbitkettle Site Investigation, NNPR. NT	Sample No.:	6012
Client:	Parks Canada Agency	Borehole/ TP:	TP-01, Sample 1
Project No.:	Y14103255-01	Depth:	0.2 m
Location:	Nahanni National Park Reserve	Date Tested	March 18-20, 2014
Description **:	SAND and SILT, trace clay, with organic material	Tested By:	NR

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
16 mm	
13 mm	
10 mm	
5 mm	
2 mm	
1.3 mm	100
630 µm	100
315 µm	99
160 µm	79
80 µm	40
33 µm	17
22 µm	12
13 µm	9
9 µm	7
7 µm	6
3 µm	5
1 µm	4



Material Description	Proportion (%)
Clay Size *	4
Silt Size	36
Sand	60
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

From toe of north river bank at 1.7 m below top of bank.

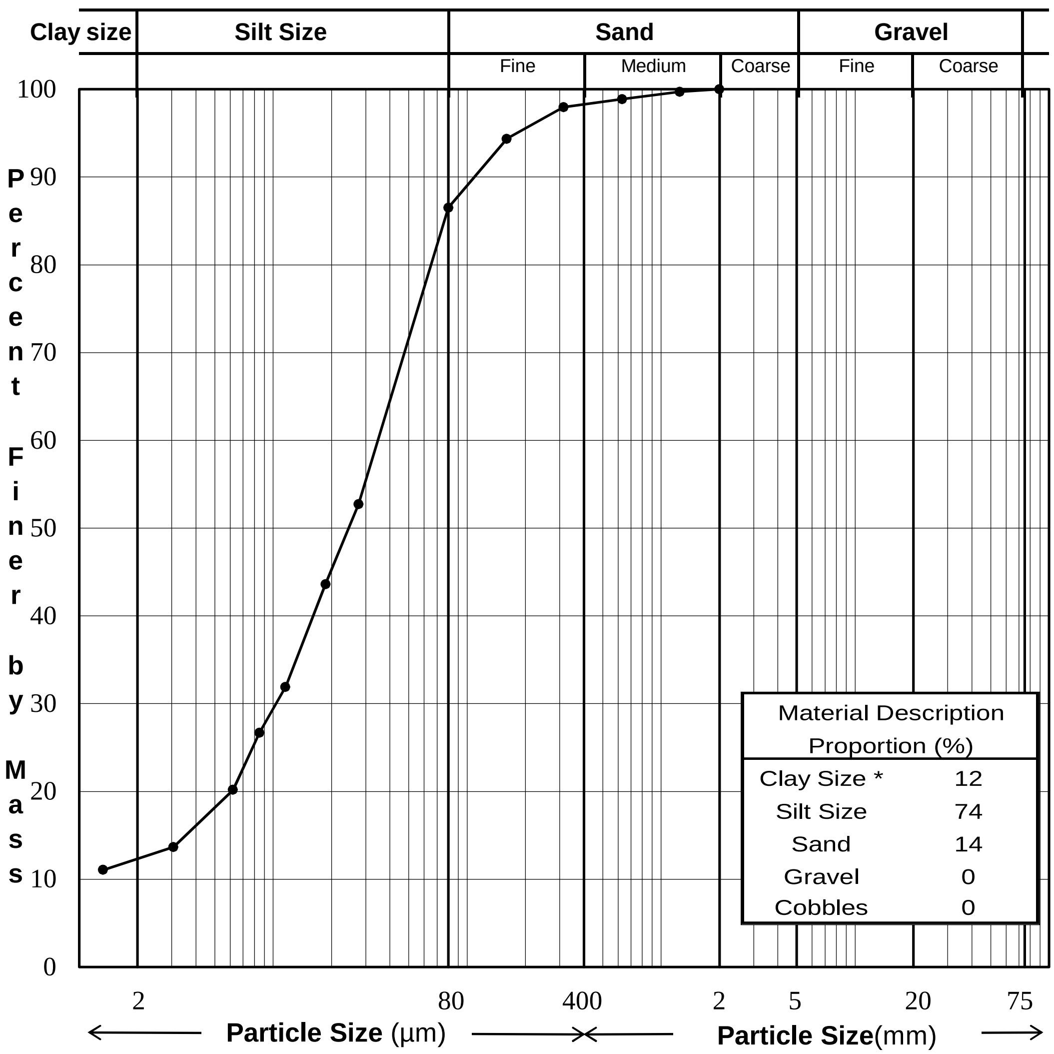
Reviewed By: RKO P.Eng.

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Rabbitkettle Site Investigation, NNPR. NT	Sample No.:	6012
Client:	Parks Canada Agency	Borehole/ TP:	TP-04, Sample S6
Project No.:	Y14103255-01	Depth:	0.2 m
Location:	Nahanni National Park Reserve	Date Tested	March 18-20, 2014
Description **:	SILT,some sand, some clay, with organic material	Tested By:	NR

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
16 mm	
13 mm	
10 mm	
5 mm	
2 mm	100
1.3 mm	100
630 µm	99
315 µm	98
160 µm	94
80 µm	87
28 µm	53
19 µm	44
12 µm	32
8 µm	27
6 µm	20
3 µm	14
1 µm	11



Material Description	Proportion (%)
Clay Size *	12
Silt Size	74
Sand	14
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Sampled near south cable post.

Reviewed By: RKO P.Eng.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Rabbitkettle Site Investigation, NNPR, NT

Project Number: Y14103255-01

Date Tested: March 13, 2014

Borehole Number: TP-01 - Sample 2

Depth: 0.3 m

Soil Description: GRAVEL and SAND, some silt/clay

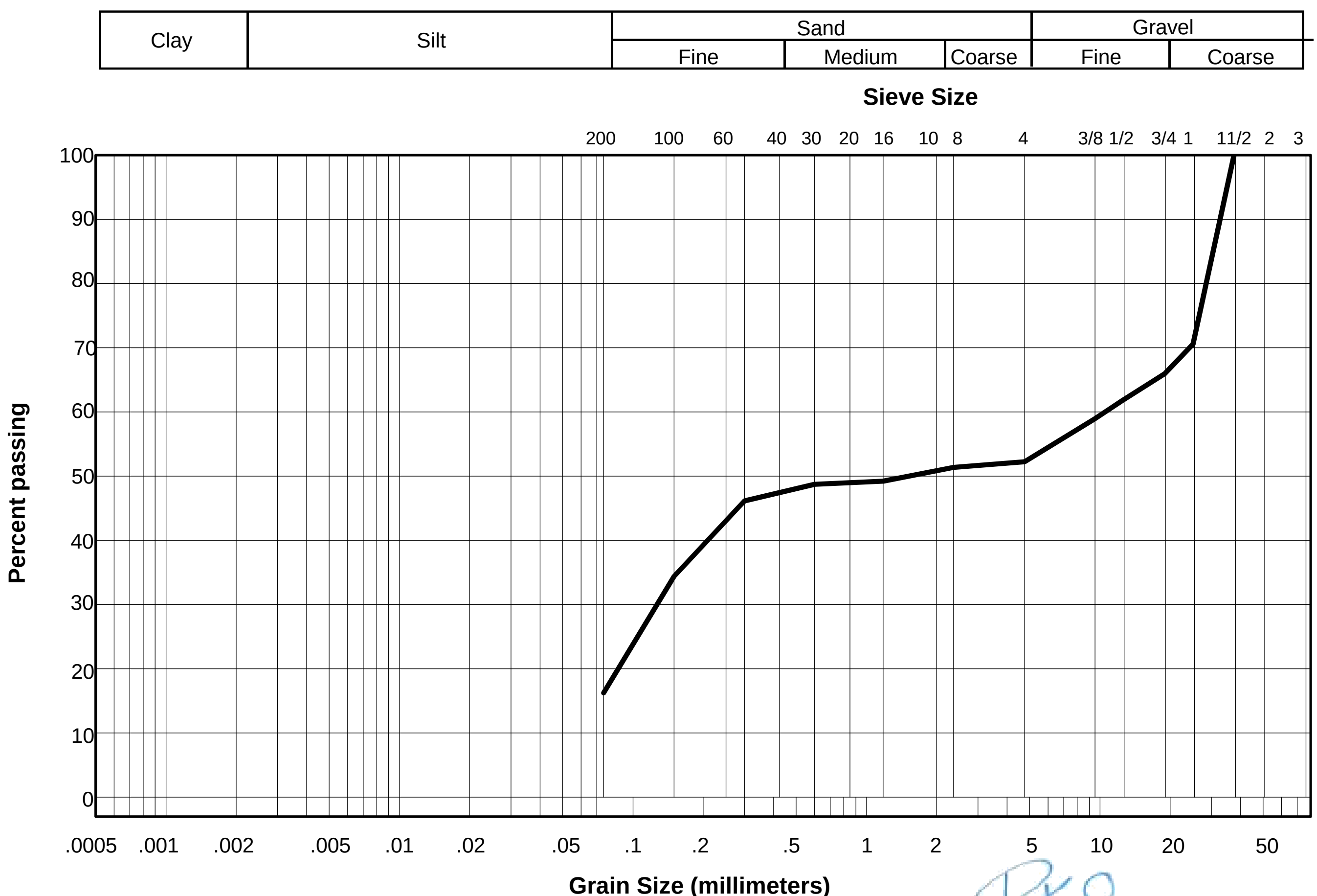
Cu:

Cc:

Natural Moisture Content: 18.7%

Remarks: From toe of north river bank at 1.8 m below top of bank.

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	100
25.000	71
19.000	66
12.500	62
9.500	59
4.750	52
2.360	51
1.180	49
0.600	49
0.300	46
0.150	34
0.075	16.3



Reviewed By: RKO P.Eng.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Rabbitkettle Site Investigation, NNPR, NT

Project Number: Y14103255-01

Date Tested: March 13, 2014

Borehole Number: TP-03 - Sample 4

Depth: 0.1 m

Soil Description: SAND, some silt/clay

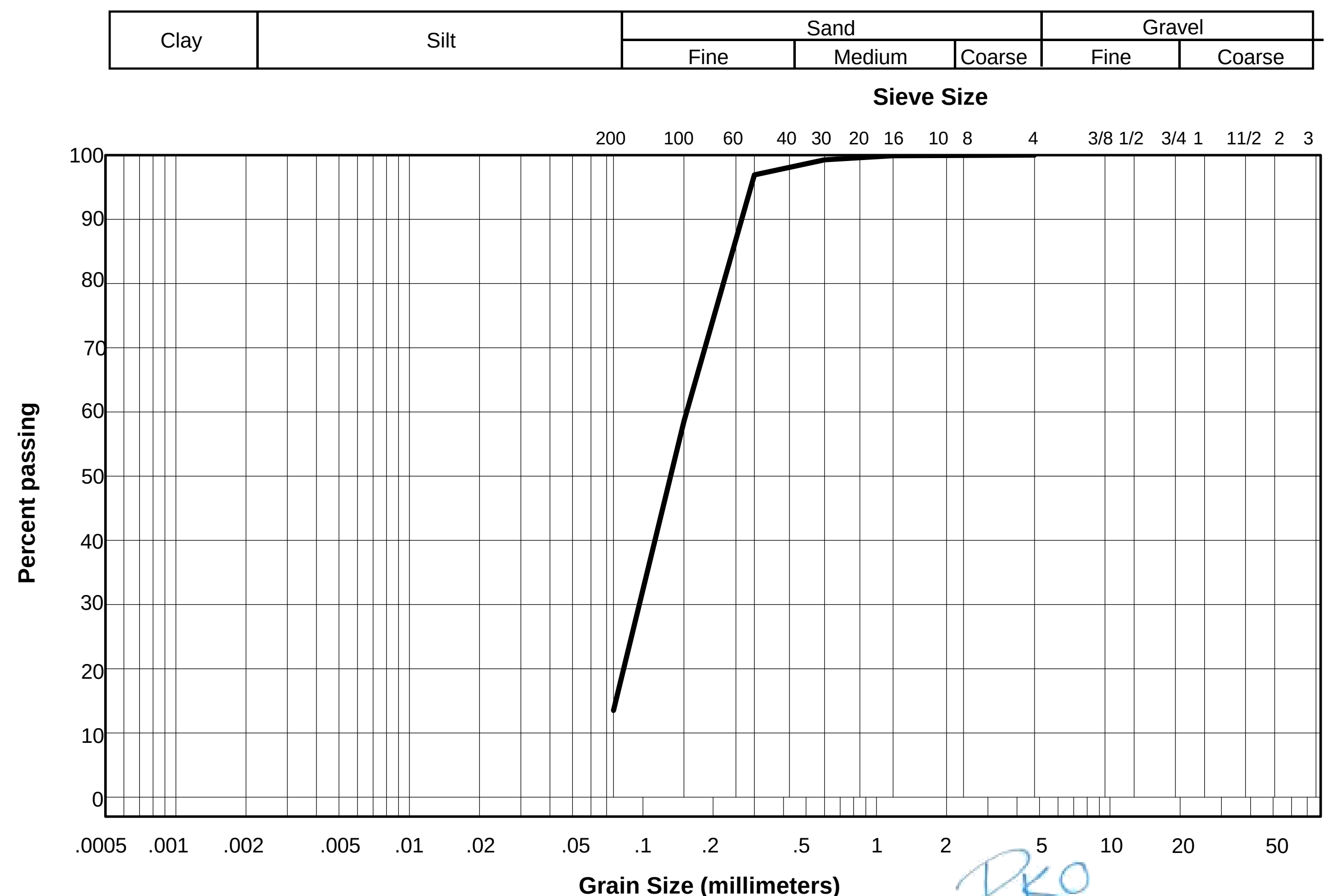
Cu:

Cc:

Natural Moisture Content: 11.7%

Remarks: From south beach.

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	#N/A
12.500	#N/A
9.500	#N/A
4.750	100
2.360	100
1.180	100
0.600	99
0.300	97
0.150	59
0.075	13.5



Reviewed By: RKO P.Eng.

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Rabbitkettle Site Investigation, NNPR, NT

Project Number: Y14103255-01

Date Tested: March 13, 2014

Borehole Number: TP-04 - Sample 6

Depth: 0.2 m

Soil Description: SILT, sandy, some clay

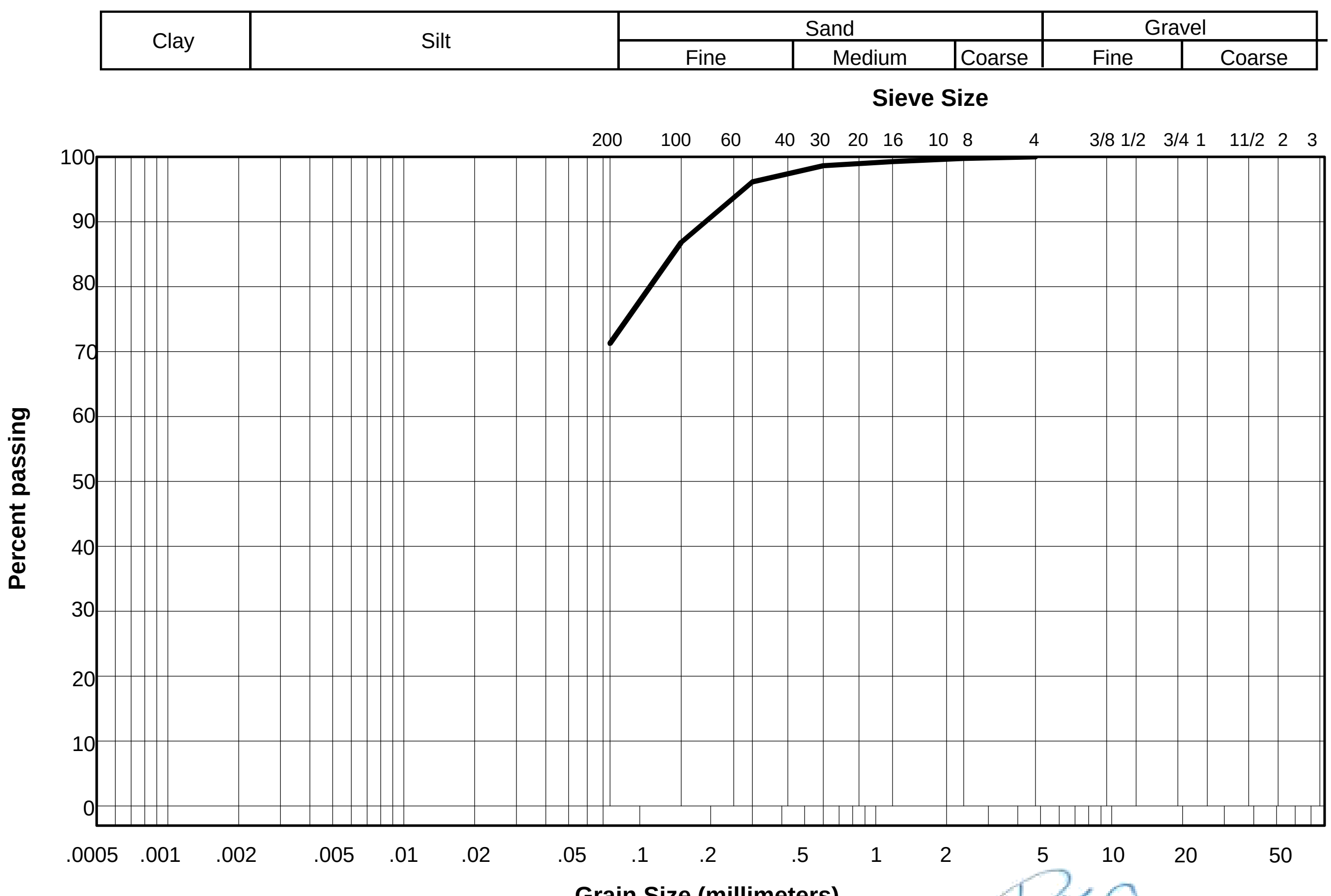
Cu:

Cc:

Natural Moisture Content: 83.8%

Remarks: Near south cable post.

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	#N/A
12.500	#N/A
9.500	#N/A
4.750	100
2.360	100
1.180	99
0.600	99
0.300	96
0.150	87
0.075	71.3



Reviewed By: RKO P.Eng.

TETRA TECH

SOLUBLE SULPHATE ION CONTENT OF SOIL

(CSA Designation A23.2-2B & A23.2-3B)

Project:	Rabbitkettle Site Investigation, NNPR	Date Tested:	March 27, 2014
Project No.:	Y14103255.01	Tested By:	JB
Client:	Parks Canada Agency	Sample Source:	TP-02 - 3
Location:	Rabbitkettle River in Nahami National Park	Laboratory:	Calgary

Sample Number						
Borehole Number	TP-02 - 3					
Depth	0.4 m					
Sulphate Content %	0.28					
Degree of Exposure (Class)	Severe S-2					

Class of exposure	Degree of exposure	Water-soluble sulphate (SO_4)† in soil sample, %	Sulphate (SO_4) in groundwater samples, mg/L‡	Water soluble sulphate (SO_4) in recycled aggregate sample, %	Cementing materials to be used§
S-1	Very severe	> 2.0	> 10 000	> 2.0	HS or HSb
S-2	Severe	0.20–2.0	1500–10 000	0.60–2.0	HS or HSb
S-3	Moderate	0.10–0.20	150–1500	0.20–0.60	MS, MSb, LH, HS, or HSb

**For sea water exposure, see Clause 4.1.1.5.*

†In accordance with CSA A23.2-3B.

‡In accordance with CSA A23.2-2B.

§Cementing material combinations with equivalent performance may be used (see Clauses 4.2.1.2, 4.2.1.3, and 4.2.1.4). Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates. Refer to Clause 4.1.1.6.3.

Limitations:

i) The degree of exposure class included herein are valid only if drainage and weeping systems meet the requirements of the site conditions.

ii) The degree exposure class should be re-verified if backfill soils for foundation walls originate from an unknown source.

Remarks:

Reviewed By: RKO P.Eng.

TETRA TECH

APPENDIX C
DESIGN AND CONSTRUCTION GUIDELINES

CONSTRUCTION EXCAVATIONS

Construction should be in accordance with good practice and comply with the requirements of the responsible regulatory agencies.

All excavations greater than 1.5 m deep should be sloped or shored for worker protection.

Shallow excavations up to about 3 m depth may use temporary sideslopes of 1H:1V. A flatter slope of 2H:1V should be used if groundwater is encountered. Localized sloughing can be expected from these slopes.

Deep excavations or trenches may require temporary support if space limitations or economic considerations preclude the use of sloped excavations.

For excavations greater than 3 m depth, temporary support should be designed by a qualified geotechnical engineer. The design and proposed installation and construction procedures should be submitted to Tetra Tech EBA for review.

The construction of a temporary support system should be monitored. Detailed records should be taken of installation methods, materials, in situ conditions and the movement of the system. If anchors are used, they should be load tested. Tetra Tech EBA can provide further information on monitoring and testing procedures if required.

Attention should be paid to structures or buried service lines close to the excavation. For structures, a general guideline is that if a line projected down, at 45 degrees from the horizontal from the base of foundations of adjacent structures intersects the extent of the proposed excavation, these structures may require underpinning or special shoring techniques to avoid damaging earth movements. The need for any underpinning or special shoring techniques and the scope of monitoring required can be determined when details of the service ducts and vaults, foundation configuration of existing buildings and final design excavation levels are known.

No surface surcharges should be placed closer to the edge of the excavation than a distance equal to the depth of the excavation, unless the excavation support system has been designed to accommodate such surcharge.

CONSTRUCTION GUIDELINE

BACKFILL MATERIALS AND COMPACTION (ALBERTA)

1.0 DEFINITIONS

"Landscape fill" is typically used in areas such as berms and grassed areas where settlement of the fill and noticeable surface subsidence can be tolerated. "Landscape fill" may comprise soils without regard to engineering quality.

"General engineered fill" is typically used in areas where a moderate potential for subgrade movement is tolerable, such as asphalt (i.e., flexible) pavement areas. "General engineered fill" should comprise clean, inorganic granular or clay soils.

"Select engineered fill" is typically used below slabs-on-grade or where high volumetric stability is desired, such as within the footprint of a building. "Select engineered fill" should comprise clean, well-graded granular soils or inorganic low to medium plastic clay soils.

"Structural engineered fill" is used for supporting structural loads in conjunction with shallow foundations. "Structural engineered fill" should comprise clean, well-graded inorganic granular soils.

"Lean-mix concrete" is typically used to protect a subgrade from weather effects including excessive drying or wetting. "Lean-mix concrete" can also be used to provide a stable working platform over weak subgrades. "Lean-mix concrete" should be low strength concrete having a minimum 28-day compressive strength of 3.5 MPa.

Standard Proctor Density (SPD) as used herein means Standard Proctor Maximum Dry Density (ASTM Test Method D698). Optimum moisture content is defined in ASTM Test Method D698.

2.0 GENERAL BACKFILL AND COMPACTION RECOMMENDATIONS

Backfill adjacent to and above footings, abutment walls, basement walls, grade beams and pile caps or below highway, street or parking lot pavement sections should comprise "general engineered fill" materials as defined above.

Exterior backfill adjacent to footings, foundation walls, grade beams and pile caps and within 600 mm of final grade should comprise inorganic, cohesive "general engineered fill". Such backfill should provide a relatively impervious surface layer to reduce seepage into the subsoil.

Backfill should not be placed against a foundation structure until the structure has sufficient strength to withstand the earth pressures resulting from placement and compaction. During compaction, careful observation of the foundation wall for deflection should be carried out continuously. Where deflections are apparent, the compactive effort should be reduced accordingly.

In order to reduce potential compaction induced stresses, only hand held compaction equipment should be used in the compaction of fill within 1 m of retaining walls or basement walls.

All lumps of materials should be broken down during placement. Backfill materials should not be placed in a frozen state, or placed on a frozen subgrade.

Where the maximum-sized particles in any backfill material exceed 50 percent of the minimum dimension of the cross-section to be backfilled (e.g., lift thickness), such particles should be removed and placed at other more suitable locations on-site or screened off prior to delivery to site.

Bonding should be provided between backfill lifts, if the previous lift has become desiccated. For fine-grained materials the previous lift should be scarified to the base of the desiccated layer, moisture-conditioned and recompacted and bonded thoroughly to the succeeding lift. For granular materials, the surface of the previous lift should be scarified to about a 75 mm depth followed by proper moisture-conditioning and recompaction.

3.0 COMPACTION AND MOISTURE CONDITIONING

"Landscape fill" material should be placed in compacted lifts not exceeding 300 mm and compacted to a density of not less than 90 percent of SPD.

"General engineered fill" and "select engineered fill" materials should be placed in layers of 150 mm compacted thickness and should be compacted to not less than 98 percent of SPD. Note that higher compaction levels may be specified within 300 mm of the design elevation. Cohesive materials placed as "general engineered fill" or "select engineered fill" should be compacted at 0 to 2 percent above the optimum moisture content. Granular materials placed as "general engineered fill" or "select engineered fill" should be compacted at slightly below the optimum moisture content.

"Structural engineered fill" material should be placed in compacted lifts not exceeding 150 mm in thickness and compacted to not less than 100 percent of SPD at slightly below the optimum moisture content.

4.0 "GENERAL ENGINEERED FILL" SPECIFICATIONS

Low to high plastic clay is considered acceptable for use as "general engineered fill," assuming this material is inorganic and free of deleterious materials.

Materials meeting the specifications for "select engineered fill" or "structural engineered fill" as described below would also be acceptable for use as "general engineered fill."

5.0 "SELECT ENGINEERED FILL" SPECIFICATIONS

Low to medium plastic clay with the following range of plasticity properties is generally considered suitable for use as "select engineered fill":

Liquid Limit	= 20 to 40%
Plastic Limit	= 10 to 20%
Plasticity Index	= 10 to 30%

"Pit-run gravel" and "fill sand" that meet the following specifications are generally considered acceptable for use as "select engineered fill."

Granular "Select Engineered Fill" – Percent Passing by Weight

Sieve Size	Pit-run Gravel (AT D6-C80)	Fill Sand
80 mm	100	--
50 mm	55 – 100	--
25 mm	38 – 100	100
16 mm	32 – 85	--
5.0 mm	20 – 65	75 – 100
630 μm	--	45 – 80
315 μm	6 – 30	--
80 μm	2 – 10	2 – 10

The "pit-run gravel" should be free of any form of coating and any gravel or sand containing clay, loam or other deleterious materials should be rejected. No oversize material should be tolerated.

The materials above are also suitable for use as "general engineered fill."

6.0 "STRUCTURAL ENGINEERED FILL" SPECIFICATIONS

Crushed gravel used as "structural engineered fill" should be hard, clean, well graded, crushed aggregate, free of organics, coal, clay lumps, coatings of clay, silt and other deleterious materials. The aggregates should conform to the following gradation requirement when tested in accordance with ASTM C136:

"Structural Engineered Fill" – Percent Passing by Weight

Sieve Size	20 mm Crush (AT D2-C20)	40 mm Crush (AT D2-C40)
40 mm		100
25 mm		70 – 94
20 mm	100	--
16 mm	84 – 94	55 – 85
10 mm	63 – 86	44 – 74
5.0 mm	40 – 67	32 – 62
1.25 mm	20 – 43	17 – 43
630 μm	14 – 34	12 – 34
315 μm	9 – 26	8 – 26
160 μm	5 – 18	5 – 18
80 μm	2 – 10	2 – 10

In addition to the above grading limits, the following criteria should be met:

"Structural Engineered Fill" – Additional Material Properties

Material Type	Percentage of Material Retained on 5 mm Sieve having Two or More Fractured Faces	Plasticity Index (<400 μm)	L.A. Abrasion Loss (percent Mass)
20 mm Crush	60 min	6 max	50 max
40 mm Crush	50 min	6 max	50 max

Materials that meet the above grading limits and material property criteria are also suitable for use as "select engineered fill."

7.0 DRAINAGE MATERIALS

"Coarse gravel" for drainage or weeping tile bedding should conform to the following grading:

"Coarse Gravel" Drainage Material – Percent Passing by Weight

Sieve Size	25 mm Gravel (AT D8-C25)	20 mm Gravel
40 mm	--	--
28 mm	--	100
25 mm	100	--
20 mm	--	85 – 100
16 mm	90 – 100	--
14 mm	--	60 – 90
10 mm	45 – 75	--
5 mm	0 – 15	0 – 10
2.5 mm	--	0 – 5
1.25 mm	0 – 5	--

"Coarse sand" for drainage should conform to the following grading limits:

"Coarse Sand" Drainage Material – Percent Passing by Weight

Sieve Size	Coarse Sand*
10 mm	100
5 mm	95 – 100
2.5 mm	80 – 100
1.25 mm	50 – 90
630 μm	25 – 65
315 μm	10 – 35
160 μm	2 – 10
80 μm	0 – 3

* From CSA A23.1-09, Table 10, "Grading Limits for Fine Aggregate", Class FA1

Note that the "coarse sand" above is also suitable for use as pipe bedding material.

8.0 BEDDING MATERIALS

The “fill sand” gradation presented above in Section 5.0 is suitable for use as pipe bedding and as backfill within the pipe embedment zone. If drainage is also a consideration, “coarse sand” presented in Section 7.0 above should be used.

CONSTRUCTION GUIDELINE

SHALLOW FOUNDATIONS

Design and construction of shallow foundations should comply with relevant Building Code requirements.

The term ‘shallow foundations’ includes strip and spread footings, mat slab and raft foundations.

Minimum footing dimensions in plan should be 0.45 m and 0.9 m for strip and square footings respectively.

No loose, disturbed or sloughed material should be allowed to remain in open foundation excavations. Hand cleaning should be undertaken to prepare an acceptable bearing surface. Recompaction of disturbed or loosened bearing surface may be required.

Foundation excavations and bearing surfaces should be protected from rain, snow, freezing temperatures, excessive drying and the ingress of free water before, during and after footing construction.

Footing excavations should be carried down into the designated bearing stratum.

After the bearing surface is approved, a mud slab should be poured to protect the soil and provide a working surface for construction, should immediate foundation construction not be intended.

All constructed foundations should be placed on unfrozen soils, which should be at all times protected from frost penetration.

All foundation excavations and bearing surfaces should be inspected by a qualified geotechnical engineer to check that the recommendations contained in this report have been followed.

Where over-excavation has been carried out through a weak or unsuitable stratum to reach into a suitable bearing stratum or where a foundation pad is to be placed above stripped natural ground surface such over-excavation may be backfilled to subgrade elevation utilizing either structural fill or lean-mix concrete. These materials are defined under the separate heading ‘Backfill Materials and Compaction’.

APPENDIX D
SIERRASLOPE INFORMATION

SIERRA®

SLOPE RETENTION SYSTEM

Design Guidelines

Tensar Earth Technologies, Inc.

TABLE OF CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This submittal introduces the Sierra® Slope Retention System to transportation agencies for review and approval as an alternative earth retention system. Provided herein is a discussion of the history, structural components, design methodologies, performance, experience, and case studies that document that this system meets all current standards for mechanically stabilized earth (MSE) systems. The Sierra System is the natural looking alternative to conventional or precast MSE retaining wall systems (Figure 1.1).

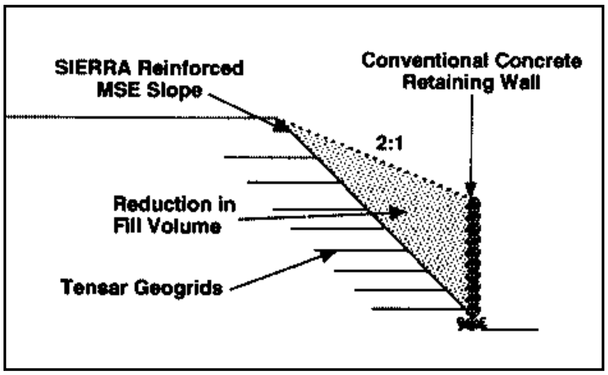


Figure 1.1 — Replacing Concrete Retaining Walls

The Sierra Slope Retention System is a complete reinforced soil slope system specifically developed for public transportation applications. The system consists of proven Tensar® Geogrids for soil reinforcement, drainage composite for internal drainage; an Erosion Control System by Tensar Earth Technologies (TET) design based on local soil types, climate, vegetation and slope angle; and the expertise of TET for design and installation. Through a combination of technologies, the Sierra Slope Retention System provides reliable performance backed by years of research and experience on completed projects worldwide.

We request that the Sierra System be approved for use and included as an alternative MSE system for all grade separation requirements including retaining walls on future agency projects.

2.0 SIERRA SYSTEM

2.1 Background

The Sierra System was developed specifically to meet, or exceed, the high standards for MSE systems set by transportation agencies. The Sierra System is an MSE system that includes:

- Tensar Geogrid soil reinforcement
- Drainage Composite
- Erosion Control Systems
- Design and engineering
- On-site technical assistance
- Twenty years of technical expertise and construction experience to handle any site-specific detail, design question, or construction issue

Throughout this manual, we will use the familiar term *Mechanically Stabilized Earth* (MSE) to describe multiple layers of reinforcement inclusions that act as reinforcement within soil fill. FHWA NHI-00-043, 2001 describes the form of MSE that incorporates planar reinforcing elements in constructed earth-slope structures with free inclinations of less than 70°, as *Reinforced Soil Slopes (RSS)*.

2.2 History

The Tensar Corporation introduced synthetic structural geogrids in North America and is the recognized leader in geogrid soil reinforcement technology. For over two decades, Tensar reinforced soil slopes have provided a natural and economical alternative to conventional MSE wall systems. The Tensar Corporation offers far more installations and experience than any other enterprise in the industry.

2.2.1 Tensar Structural Geogrids

Tensar Geogrids were developed in the late 1970s by Netlon Limited of Blackburn, England, specifically for permanent reinforcement of soil and aggregate materials. Principal applications are roadway subgrade improvement and base reinforcement, reinforced soil retaining walls, reinforced soil slopes, and embankments constructed over soft ground. The first installation of Tensar Geogrids in the United States was a Tensar reinforced soil slope in 1982 for the Texas State Department of Transportation. Since then, thousands of projects have been completed and are performing successfully. **There have been no known failures of Tensar reinforced soil slopes due to failure of the product or technology since its development.**

Tensar Geogrids have been manufactured in Morrow, Georgia since 1984.

2.2.2 Erosion Control Systems

The Tensar Corporation has been designing erosion control systems for reinforced slopes since the first installation in North America in 1982 for the Ministry of Transportation - Ontario, Canada. Effective vegetative erosion control systems combine engineered products as well as horticultural technologies. The experience of Tensar Earth Technologies in the design and construction of hundreds of Sierra Slopes, in a wide variety of climates using several types of vegetative systems, is unparalleled in the industry.

2.3 Material Components

Tensar Geogrids, drainage composites and erosion control systems combine to form a safe, reliable, and durable slope system that offers a very cost-effective alternative to retaining walls. Figure 2.1 illustrates a typical Sierra Slope.

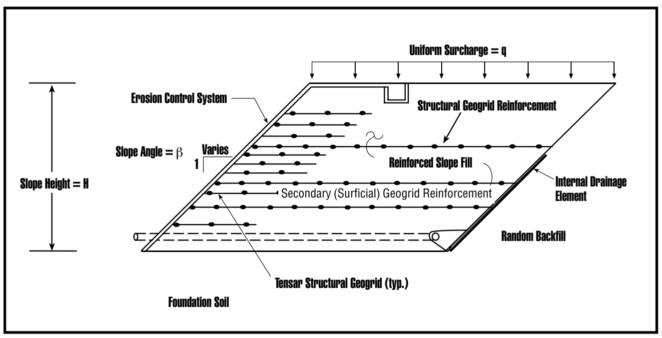


Figure 2.1 — Typical Section, Sierra Slope Retention System

2.3.1 Tensar Structural Geogrids

Tensar Geogrids are made of select high density polyethylene (HDPE) and polypropylene (PP) to offer maximum long-term performance. Tensar Geogrids are durable in the presence of virtually every fill soil typically used in highway construction and are inert to electro-chemical corrosive attack.

Tensar Geogrid reinforcement consists of a regular network of integrally connected longitudinal and transverse polymer tensile elements. The open aperture geometry is designed to create significant mechanical interlock with surrounding soil, aggregate, or other fill material. Because of this, Tensar Geogrids can be used to effectively reinforce most soils and are not limited to use in select granular fill.

Structural geogrids are manufactured through a series of precise steps. The result is a unique material with specific performance capabilities as a soil reinforcing element. Both the Tensar manufacturing process and the Tensar product are covered by U.S. patents.

A brief summary of the manufactured process has been presented by Wrigley.

> "A simplified depiction of the manufacturing process is presented in Figure 2.2. Accurately controlled polymer (typically HDPE or PP) sheet is first punched with a precise pattern of holes. This punched sheet is then drawn in the machine, longitudinal direction under closely controlled conditions at a temperature below the melting point of the chosen polymer. This produces either a 'uniaxial' geogrid or feed stock for subsequent transverse drawing into a 'biaxial' geogrid. The form and performance of these patented products is controlled by the precision of the thickness and holes of the 'punched' sheet and the drawing conditions.
>
> In the extruded sheet, the polymer is in the form of essentially randomly arranged small crystallites separated by thin amorphous zones. Most molecules are sufficiently long to pass through several crystallites thus linking them together with strong molecular chains (Wrigley[2]). During drawing below melting temperature the crystallites and the molecular chains in the amorphous zones are aligned (oriented) in the direction of draw. The importance of this continuation of molecular orientation into the junction zones on load-bearing performance was recognized in the product patents."

The Tensar Corporation operates a comprehensive Quality Assurance (QA) program in its manufacturing plant[3]. Quality Control (QC) is independently conducted by a separate department/laboratory.

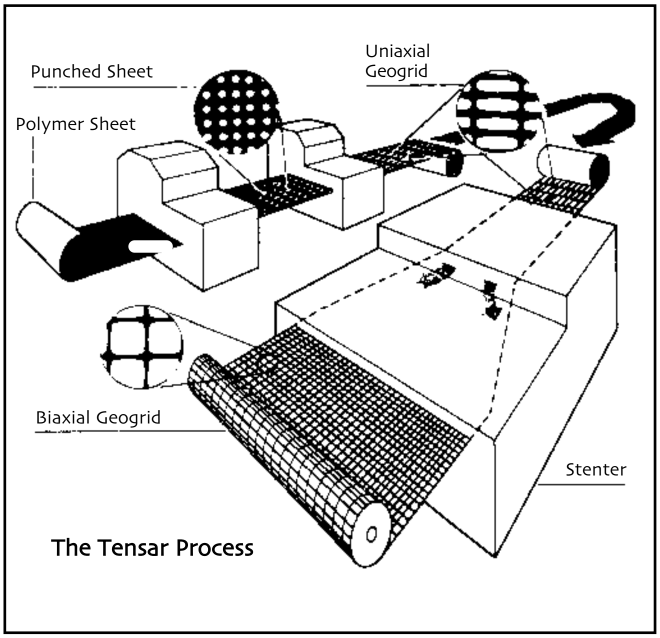


Figure 2.2 — Processing Tensar Geogrids

2.3.2 Drainage Composite
Drainage composite consists of a geotextile bonded to both sides of an integrally formed polyethylene geonet structure with uniform channels, open area, and thickness to assure uniform flow throughout the structure.

2.3.3 Erosion Control System
The erosion control system is generally composed of a combination of long-term nondegradable Turf Reinforcement Mats (TRMs), structural geogrids, SierraScape™ facing elements, geotextile or other approved facing products. These materials can be used alone or in combination.

Tensar Earth Technologies offers two TRM products, TM3000 and TB1000. Each are typically specified for a particular project based on local soil types, climate, vegetation, slope angle, aesthetics, and maintenance considerations. For more information on either product, please see Tensar Earth Technologies' TRM Brochure. You may order a copy by calling 800-TENSAR-1, e-mailing info@tensarcorp.com, or visiting www.tensarcorp.com.

The typical erosion control system will employ a biotechnical design using engineering technology and horticultural experience that relies on a combination of geosynthetic materials as well as vegetation to create a stable and aesthetic slope facing system. To address these issues and provide a design that will function well under local environmental conditions, Tensar has consulted with landscape architects experienced in providing local and regional designs for plant selection, landscape design, and erosion control solutions for the Sierra Slope Retention System. Sierra Slope erosion control systems typically will specify products from a list of pre-approved systems. Vegetation options to provide a complete and stable facing solution can be specified by the agency or by Tensar, but supply of the vegetation is by others.

2.4 System Supply

The Sierra Slope Retention System is a complete package system, including materials, engineering design and on-site technical assistance. All material components are proven, and are provided with quality assurance documentation.

2.5 System Approval

The recent growth of geosynthetic reinforcement types and suppliers of such geosynthetics requires consideration of different alternatives prior to preparation of contract documents so that contractors are given clear direction as to which systems are acceptable. The FHWA has outlined proposed guidelines for the review and approval of reinforced slope systems[4]. The following sections are based on those recommendations.

A) A supplier or their representative requests in writing prior to bid to be placed on this list.

B) The Agency approves the system and the supplier based upon the following considerations:
   i) The geosynthetic reinforcement, drainage details, and erosion control system for the system be reviewed and approved for use as a complete system.

   ii) The supplier must have a large enough operation and necessary experience to supply and support the construction on a timely basis.

iii) Because the proposed applications are for critical structures, past experience in construction must be documented. Suppliers shall provide certificate of insurance showing adequate professional engineers "Errors and Omissions" insurance.

To facilitate review by the Agency, the supplier must submit a package which satisfactorily addresses the following items:

A) System development and year it was commercialized

B) Organization structure of the supplier of the system including specific engineering and construction support personnel

C) Limitations and disadvantages of system

D) List of users including names, addresses, and telephone numbers

E) Erosion control details as a function of climactic, geographic, and slope steepness features

F) Sample material and construction control specifications - showing material type, quality, certifications, field testing, and placement procedures

G) A well documented field construction manual describing in detail, and with illustrations where necessary, the step by step construction sequence (copies of this manual should also be provided to the contractor and the project engineer at the beginning of the slope construction)

H) Typical unit costs, supported by data from actual projects

I) Detailed information on slope design and slope stability analysis techniques

J) Material acceptance and rejection criteria: as outlined in Appendix A of this document. Actual test data must be provided to substantiate adherence to the FHWA guidelines

3.0 SIERRA SLOPE DESIGN

3.1 Design Standards

Design requirements for MSE slope structures are set forth in FHWA NHI-00-043, "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines." Reference is made to applicable American Society for Testing of Materials (ASTM) test standards for the erosion control system, geogrid reinforcement, and drainage composite materials. Applicable Geosynthetic Research Institute (GRI) test standards and standards of practice are also referenced where ASTM standards do not yet exist.

3.2 Terminology

A mechanically stabilized earth (MSE) slope consists of six major components: 1) reinforced slope fill; 2) random backfill behind the reinforced zone; 3) foundation soil; 4) structural geogrid reinforcement; 5) internal drainage element; and 6) erosion control system (Figure 2.1).

3.3 Design Overview

The Sierra Slope Retention System is designed so that it is stable, both internally and externally. Internal stability requires that the reinforced soil structure is coherent and self-supporting under the action of its own weight and any externally applied forces. This is accomplished through stress transfer from the soil to the structural geogrid reinforcement by friction and passive resistance mobilized by interlock.

The self-supporting gravity mass is created by the structural geogrid reinforced soil. The erosion control system is used to prevent surface sloughing of the slope face, provide an aesthetic exterior finish and can also facilitate compaction of the reinforced slope fill.

The steps in the design of a Sierra Slope Retention System are:

- Qualifying geogrid design assumptions
- Defining soil, geometry, reinforcement, and loading parameters
- Determining slope stability calculations
- Qualifying assumptions for internal drainage, erosion control system, and landscape design
- Developing construction drawings & specifications

3.3.1 Design Assumptions
The design methods presented herein are directly applicable to each Sierra Slope meeting the following assumptions:

1. The soil parameters for the reinforced, retained, and foundation soils are defined. Reinforced fill may include all highway embankment construction fills and is not limited to select or granular backfill.

2. Design strength (T_a) of the geogrid reinforcement is approved by the agency prior to design based on FHWA Guidelines[4] with consideration of installation damage, creep, chemical and biographical degradation, and joints.

3. Geogrid-soil interaction coefficients (C_i) for the structural geogrid are approved by the agency prior to design based on review of pullout tests using GRI:GG5 test methods[5] conducted with representative soils or site specific testing.

4. Soil reinforcement is provided by horizontal layers of Tensar Geogrids as outlined on project specific design drawings.

5. Any loads anticipated above and behind the reinforced zone are accounted for in the design.

6. Positive drainage is provided to assure no hydrostatic forces develop in the reinforced zone.

7. If seismic forces are to be considered in this design, the appropriate gravitational force must be defined.

8. Slope angle, surficial stability and facing material/vegetation selection must be considered in the design of the erosion control system.

3.3.2 Total Stress vs. Effective Stress Parameters
An important element of slope stability analysis is soil shear strength. When choosing value(s) it may be necessary to consider both total and effective stresses. These analyses are relevant to short-term (or end-of-construction) stability and long-term stability, respectively. Prior to performing a design, available soil information from testing should be appropriately classified into one of these two categories.

In total, stress (undrained or short-term) analysis failure due to shear stresses and increased pore pressure during construction is assumed. This situation occurs in clays when pore water pressure induced by construction has not had time to dissipate. In this case, the shear strength of the soil is attributed only to cohesion (i.e. $\phi = 0$).

Effective stress (drained or long-term) analysis is used for most natural slopes and embankments. Pore pressures are assumed to be in equilibrium and are determined by the groundwater table or a known steady flow pattern. When using effective stress parameters, attention to the type of soil test and expected in-situ soil conditions are particularly important.

3.3.3 Geometry
For a typical slope, the slope height, H (ft or m), slope angle β (degrees), and uniform surcharge, *q* (lb./ft^2 or kN/m^2), are illustrated in Figure 2.1. Complicated geometries such as broken back slopes, transition slopes or unusual foundation conditions can also be designed. The dimensions and slope angles for these geometries must be known. In addition, a value for minimum vertical spacing between geogrid layers, s_{min} (ft or m), is required. As a construction expedient s_{min} is usually set equal to the soil lift thickness to be used during construction.

3.3.4 Structural Geogrid Reinforcement Parameters
The Sierra Slope Retention System consists of Tensar Geogrids arranged in horizontal planes in the backfill to resist outward movement of the reinforced soil mass. Geogrids transfer stress to the soil through passive soil resistance on transverse members of the grid and friction between the soil and horizontal surfaces of the geogrid[6]. Geogrid long-term design strength (T_a) is determined by long-term creep testing. Durability factors include site damage, chemical degradation, and biological degradation. The degradation caused by these factors may result in either a decrease in tensile strength of the geogrid or a decrease in tensile strength of the geogrid/ soil interaction (coefficient of interaction, C_i). Values for T_a and C_i should be selected based on the geogrid and soil type used in the reinforced slope fill. The methods for quantifying these parameters are presented below with detailed discussion in Appendices A and B.

For Sierra and all other MSE slopes, the allowable geogrid design strength [4]T_a is:

$$T_a = \frac{T_{ULT}}{RF_{CR} \times RF_{ID} \times RF_D}$$

T_a = allowable geogrid tensile strength, for use in stability analyses

T_{ULT} = ultimate geogrid tensile strength per ASTM D6637

RF_{CR} = reduction factor for creep rupture and ratio of T_{ULT} to creep rupture strength (dimensionless)

RF_{ID} = reduction factor for installation damage (dimensionless)

RF_D = reduction factor for durability/aging (dimensionless)

3.3.5 Slope Stability

The techniques used for analysis of Tensar MSE slopes are an extension of routine slope stability procedures. An MSE slope, however, is more complex than an unreinforced slope and requires more steps in the analytic process. Permanent, critical, geogrid reinforced structures should be designed using comprehensive slope stability analysis. A structure may be considered permanent if its design life is greater than 5 years. A reinforcement application is considered critical if there is mobilized tension in the reinforcement for the life of the structure, if failure of the reinforcement results in failure of the structure, or if the consequences of failure include personal injury or significant property damage[7].

Failure modes of MSE slopes include[4]:

i) internal, where the failure plane passes through the reinforcing elements
ii) external, where the failure surface passes behind and underneath the reinforced mass
iii) compound, where the failure surface passes behind and through the reinforced soil mass

A MSE slope may have several potential "critical" failure planes[8]. Tensar Sierra Slope Retention System designs consider the number of reinforcement layers, design tensile force of each layer, anchorage requirements, and length of the reinforcing layers which affect the location of the critical failure plane. The critical failure surface will most likely not be the same as the unreinforced failure surface with the lowest factor of safety. Therefore, a computerized search of all potential failure surfaces within the "safe" unreinforced failure zone should be conducted. Additionally, safety factors may be plotted as contours of safety factors. The contours should be drawn on the field of failure circle centroids[8]. This plotting assists in locating the various centroids of failure circles with low safety factors, and in locating all potential critical failure surfaces (Figure 3.1).

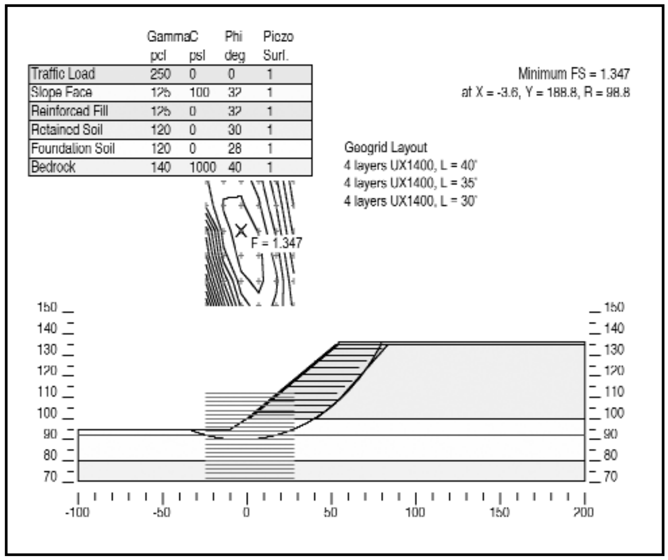


Figure 3.1 — Typical Critical Failure Surfaces for an MSE Slope

Comprehensive slope stability analysis requires the use of a computer program. TET uses a slope stability computer program that incorporates the stabilizing effects of Tensar Geogrid reinforcement into the analysis of a slope using the Simplified Bishop Method of Slices. This computer program directly incorporates tension of each reinforcement layer into the safety factor computations. The program includes anchorage, or pullout length requirements in computation of mobilized reinforcement tension.

3.3.6 Analysis Methods

3.3.6.1 Limit Equilibrium Methods. The object of slope stability analysis is to quantify the possibility of excessive deformation or collapse of the slope or embankment. The accurate prediction of deformation requires definition of many hard-to-evaluate parameters and use of complex analytical methods not available to most engineers. Thus, analysis using limit equilibrium to determine a factor of safety against collapse of the slope is most commonly used. It is assumed by requiring an adequate factor of safety through limit equilibrium methods that deformations of the slope will be limited to an acceptable level.

3.3.6.2 Simplified Bishop Method of Slices. The Bishop Method of Slices may be used to analyze the stability of slopes with varying soil properties, pore water pressure, and an irregular geometry. The failure surface is assumed circular and the soil mass is divided into vertical slices. The forces on each slice are evaluated using limit equilibrium methods (i.e. summing moments about the center of rotation of the failure plane).

The forces acting on each slice of a slope include the weight of the slice, W; normal and shear forces acting on the base of the slice, P and S; normal and shear forces acting on the vertical sides of the slice, E and T. (Figure 3.2) The vertical normal and shear forces are related to deformation and stress-strain characteristics of the soil which are not easily evaluated. To achieve a statically determinate system, the "simplified" method assumes side forces to be equal with coincidental lines of action. Thus, the forces cancel each other and are set equal to zero in calculations. The effect on the accuracy that this assumption has on the determination of the factor of safety of the slope is in the range of 1% to 10%.

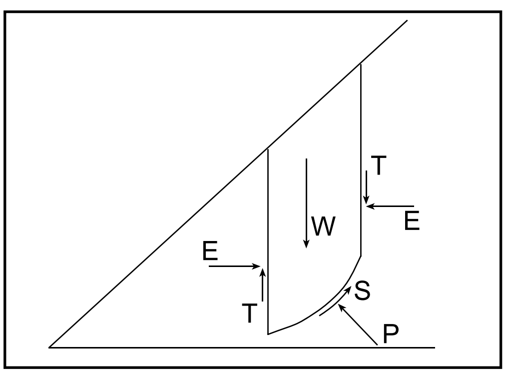


Figure 3.2 — Forces Acting on a Typical Slice

3.3.7 Safety Factors

The factor of safety for slope stability should be adequate to address all uncertainties in the assumptions and design[9]. Recommended minimum stability factor of safety is 1.3 against external, deep seated failures; compound failure surfaces; and internal failure[4], unless local codes require a higher value.

This safety factor is the minimum recommended for permanent structures. Higher factors are recommended in the absence of thorough geotechnical investigation and analysis. **Higher factors may also be desired in cases where slopes are supporting structures.** Lower safety factors may be acceptable for temporary and/or noncritical structures.

3.3.8 Seismic Design[4]

Under seismic loading, a reinforced soil slope is subjected to dynamic forces in addition to static forces. The allowable tensile stress of the geogrid reinforcement may be increased for short-term seismic loading conditions[9,10].

The recommended method of seismic analysis for earth slopes is pseudo-static analysis with a slope stability computer program. A horizontal pseudo-static force, which is some percentage of the slice weight, is applied to each slice in the analysis. A vertical force may also be simultaneously applied, if dictated by local codes or practice. Internal, external, and compound failure modes should be analyzed with an additional horizontal pseudostatic acceleration force included. The target safety factor is typically taken as greater than or equal to 1.1 for these potential failure modes.

The magnitude of the pseudo-static force coefficient will typically be dictated by local codes and/or practice. A detailed map seismic risk is presented in the AASHTO Bridge Manual (1991). Pseudo-static techniques may not be appropriate for areas subject to high seismic loadings or slopes adjacent to critical structures[10]. Comprehensive dynamic analysis procedures should be utilized for these cases.

Use of pseudo-static dynamic earth pressures according to the Mononobe-Okabe procedure may be acceptable for slopes steeper than approximately seventy degrees (70°)[9]. This pseudo-static analysis was developed for retaining walls and assumes that the soil behind the wall behaves as a rigid body. The factor of safety against failure by outward sliding should be greater than or equal to 1.1. This wall analysis is also sensitive to the slope angle of the retained backfill, as discussed in Supplement A, Standard Specifications for Seismic Design of Highway Bridges, of the AASHTO Bridge manual (1991) and by Seed and Whitman[11].

3.4 Soil-Reinforcement Interaction

Two types of soil-reinforcement interaction coefficients or interface shear strengths must be determined for design: pullout coefficient and direct shear coefficient[12]. Pullout coefficient is used in stability analysis to compute mobilized tensile force at the front and tail of each reinforcement layer. The direct shear coefficient is used in checking factors of safety against outward sliding of the reinforced mass on top of any layer of reinforcement. A detailed discussion on the use of these coefficients is provided by the FHWA[4].

A test method standardizing laboratory pullout testing of geogrids (GRI:GG5) was published by the Geosynthetic Research Institute (GRI) in 1991[5]. Determination of an interaction coefficient is defined as either short-term or long-term by this standard, and is dependent on the method of pullout force application. Short-term testing with controlled strain rate, controlled stress rate, or incremental stress methods of pullout force application provide short-term interaction coefficients. A constant stress (creep) method of pullout force application yields a long-term pullout coefficient. Typical design practice is to define an interaction coefficient with a controlled strain (deformation) method of testing, per the GRI test method, and apply the coefficient to long-term designs.

TET has performed long-term pullout tests of both singular and composite manufacture type of geogrids[13]. The results of approximately 1,000-hour sustained load pullout tests were compared with a quick pullout test (strain rate of 1 mm/min) to determine an efficiency of the geogrid with respect to pullout. Efficiency was computed as the ratio of long-term coefficient of interaction to the short-term coefficient of interaction. Use of quick tests to define long-term pullout capacity for use in design is not recommended. This practice inherently assumes that an efficiency of 100% or greater exists between long-term and short-term pullout capacity.

However, the pullout test results presented by Collin and Berg[13], demonstrate that it can not be assumed that the long-term pullout performance of geogrids can be determined through quick tests. Short-term coefficient of interaction C_{is} may not be equal to the long-term coefficient of interaction C_{is}. This testing substantiates that "through-the-junction" creep testing outlined in GRI:GG3 is critical when determining the long-term coefficient of interaction through quick tests.

3.5 Internal Water Drainage

Uncontrolled subsurface water seepage can decrease stability of MSE slopes and could ultimately result in slope failure. Hydrostatic forces on the rear of the reinforced mass will decrease stability against sliding failure. Uncontrolled seepage into the reinforced mass will increase the weight of the reinforced mass and may decrease the shear strength of the soil, hence decrease stability. Seepage through the mass can reduce pullout capacity of the geogrid at the face and increase soil weight, creating erosion and sloughing problems. A detailed discussion of internal drainage is provided by the FHWA[4].

Design of subsurface water drainage features must address flow rate, filtration, placement, and outlet details. Drains are typically placed at the rear of the reinforced mass. Lateral spacing of outlets is dictated by site geometry, expected flow, and existing agency standards. Outlet design should address long-term performance and maintenance requirements as applicable.

Drainage composites can be utilized in subsurface water drainage design for Sierra Slopes. The use of geocomposite drainage is briefly addressed in this document with specifications provided in Section 7.0. Drainage composites should be designed with consideration of:

i) peel strength of the geotextile from the geonet
ii) reduction of flow capacity due to intrusion of geotextile into the core
iii) inflow/outflow capacity
iv) filtration characteristics between the soil and geotextile

A measurement of peel strength of the geotextile from the geonet is an important consideration to insure that a sheer failure does not occur from the load created by the backfill on the drainage composite. ASTM F904-84 test procedure Comparison of Bond Strength or Ply Adhesion of Similar Laminates made from Flexible Materials should be followed.

Intrusion of the geotextiles into the core and inflow/outflow capacity should be measured with a substained transmissivity test. The ASTM D 4716 test procedure (1987), Constant Head Hydraulic Transmissivity of Geotextiles and Geotextile Related Products, should be followed. Load should be maintained for 50 hours or until equilibrium is reached, whichever is greater, at a pressure equal to or greater than the expected pressure for the specific application. Flow rate is measured at a standard gradient of 1.0. In addition, slope stability analysis should account for interface shear strength along a geocomposite drain. The geotextile that is laminated to the geonet should be designed to act as a filter to prevent the migration of soil. Guidelines for the filter design are provided in the FHWA Guidelines[4].

Special emphasis on the design and construction of subsurface drainage features is recommended for MSE slope structures. Drainage is critical for maintaining slope stability. Redundancy in the drainage system is also recommended.

3.6 Surface Drainage & Erosion Protection

Stability of a slope can be threatened by erosion due to surface water runoff. Erosion rills and gullies can lead to surface sloughing and possibly deep seated failures. Erosion control and revegetation measures must be an integral part of all reinforced slope system designs and specifications.

3.6.1 Surface Water Drainage

Surface water runoff should be collected above the reinforced slopes and channeled or piped below the base of the slope. Standard agency drainage details should be utilized. It is also important not to allow surface waters to infiltrate from the top of the slope into the reinforced slope fill. This water will tend to percolate out of the slope face potentially causing surficial slumps.

3.6.2 Surficial Stability

In-depth discussions of surficial slope failure mechanisms have been presented by Terzaghi and Peck (1967)[14], Campbell (1975)[15], and Theilen and Collin (1993)[16]. These failures are usually initiated by water infiltrating the near surface soils. The source of this water may be rainfall, broken utilities, landscape watering, or failure to intercept upslope drainage. When infiltration exceeds the transmissivity of the soil, a perched water table with seepage parallel to the slope face can develop. Intermediate layers of secondary reinforcement are usually required at the face of reinforced slopes to control surficial slope failures. Design is dependent upon soil type, slope angle, slope height, and primary reinforcement spacing. The intermediate layers of reinforcement aid in achieving compaction at the face, thus increasing soil shear strength and resistance to erosion. These layers also act as reinforcement against shallow or sloughing types of slope failures. Intermediate reinforcement is typically placed on each or every other soil lift, except at lifts where primary structural reinforcement is placed. Intermediate reinforcement is also placed horizontally adjacent to primary reinforcement, and at the same elevation as the primary reinforcement, when primary reinforcement is placed less than 100% coverage in plan view. The intermediate reinforcement typically extends 3 to 6 feet into the fill from the face.

Slopes steeper than 1:1 typically require facing support during construction. TET's SierraScape facing elements are typically used. SierraScape facing elements are mechanically connected to the geogrid reinforcement providing enhanced protection against surficial failure during and immediately following construction.

3.6.3 Landscape Design Considerations

Unlike conventional MSE wall systems, the Sierra Slope Retention System can be designed for a wide variety of visual impressions. Sierra Slopes can be faced with grass or wildflowers, revegetated to a natural state or landscaped as mulched ornamental bedding. Sierra Slopes can also be combined with traditional flat fill slopes to create contoured grades that are indistinguishable from adjacent natural slopes.

The various vegetation options available for the Sierra Slope Retention System place an emphasis on choosing the proper landscape design to fit the site constraints. A low maintenance grassed slope may work well on a seldom seen highway downslope, but may be a poor choice for a slope on a highly visible urban roadway interchange. A landscaped slope may be a better choice for the latter site.

Landscape design is usually provided by the agency. TET can provide local and regional expertise in landscape design, plant selection, and erosion control solutions for Sierra Slopes.

3.6.4 Erosion Control Systems
MSE slopes typically are vegetated during or immediately after construction to prevent or minimize erosion due to rainfall and runoff on the face. On sites where vegetation cannot grow (i.e., abutments under bridges, below water, desert, or arid regions) non-vegetated erosion control systems can be provided. Vegetation requirements will vary by geographic and climactic conditions and are therefore project specific. Steep grades can be difficult locations on which to establish and maintain vegetative cover. The steepness of the grade limits the amount of water absorbed by the soil before runoff occurs. Once vegetation is established on the face, it must be protected to ensure long-term survival.

Consequently, for grassed or wildflower faced slopes, a long-term nondegradable erosion control mat that is stabilized against ultra-violet light and is inert to naturally occurring soil-born chemicals and bacteria is required. The erosion control mat serves four functions:

A. Protects the bare soil face against erosion until vegetation is established
B. Reduces runoff velocity for increased water absorption by the soil thus promoting long-term survival of the vegetative cover
C. Reinforces the root system of the vegetative cover to create veneer reinforcement element for the sod
D. Protects seed and enhances seed germination and seedling establishment over the design life of the structure to ensure complete vegetation cover on the entire slope face. Sierra Slopes usually employ low maintenance vegetation options but depending on the site and actual plant material selected, some maintenance of vegetation may be required.

3.6.5 Erosion Control System Selection
Selection of the appropriate vegetation and an erosion control system is a four-step process. These steps are:

A. Agency determines or designs desired slope angles based on site constraints, soil types, etc.
B. Agency and/or supplier reviews the surrounding site for existing vegetation, visibility factors, and horticultural growing conditions.
C. Agency chooses vegetation option based on considerations outlined above.
D. Agency specifies appropriate erosion control system as a pre-approved system.

The Sierra approach for erosion solutions uses several predetermined erosion control systems. This approach is preferable to a component or material approach, because it can address the multitude of factors that must be considered in designing erosion control and facing treatments and it simplifies the approval process for the Agency. The erosion control system approach addresses surficial bare soil erosion control, vegetation establishment, surficial stability, facing support during construction, and facing aesthetics.

4.0 SIERRA EXPERIENCE

Some of the completed Sierra Slope Retention System projects for government agencies are summarized below. Additional information, including contact people, on these projects is available upon request. *An extensive completed project list for slopes used in property development is also available upon request.*

ALABAMA

Project: County Rd 81
Location: Ft. Payne, Alabama
Owner: Dekalb County
Engineer: Ladd Environmental Consultants, Inc. and Gallet & Associates
Contractor: Jackson Paving
Constructed: Winter 1999
Max. Height: 63 ft.; 1:1 slope

ARIZONA

Project: Bush Highway
Location: Maricopa County, Arizona
Owner: Maricopa County, Arizona
Engineer: Maricopa County Highway Department
Contractor: McMurry Bros.
Constructed: Fall 1987
Max. Height: 70 ft.

Project: Carefree Highway
Location: Maricopa County, Arizona
Owner: Maricopa County, Arizona
Engineer: Tensar Earth Technologies, Inc.
Contractor: Ames Construction
Constructed: Spring 1993
Max. Height: 35 ft; 1:1 slope

ARKANSAS

Project: Cannon Creek, Highway 16
Owner: Arkansas State Highway and Transportation Department
Engineer: Raymond Technical
Contractor: Machen Construction
Constructed: Summer 1987
Max. Height: 75 ft.; 2:1 slope repair

Project: Fort Smith
Location: Fort Smith, Arkansas
Owner: City of Fort Smith
Engineer: Mickale, Wagoner & Coleman
Contractor: Forsgren Construction
Constructed: Summer 1996
Max. Height: 22 ft.

CALIFORNIA

Project: Highway 84
Location: LaHonda, California
Owner: Cal Trans
Engineer: Cal Trans District 4
Constructed: Fall 1986
Max. Height: 42 ft.; 1:1 slope

Project: Highway 9
Location: Felton, California
Owner: Cal Trans
Engineer: Cal Trans District 4
Contractor: Dan Caputo
Constructed: Summer 1992
Max. Height: 46 ft.; 0.5:1 slope

Project: Van Duzen-Peanut
Location: Northern California
Owner: USDA Forest Service
Engineer: FHWA; Central Division
Contractor: Stimpl-Wiehelhaus
Constructed: Fall 1988
Max. Height: 60 ft.; 1:1 slope

COLORADO

Project: I-270
Location: Denver, Colorado
Owner: Colorado DOT
Engineer: Colorado DOT
Contractor: Cat Construction
Constructed: Spring 1994
Max. Height: 14 ft.; 1.25:1 slope

FLORIDA

Project: State Road 70 Overpass
Location: Okeechobee, Florida
Owner: Florida DOT
Engineer: Professional Engineering Consultants
Contractor: Sheltra Construction Company
Constructed: Summer 1996
Max. Height: 28 ft.; 1:1 slope

Project: State Road Highway 60
Location: Lake Wales, Florida
Owner: Florida DOT
Engineer: Jammal & Associates
Contractor: Mid States Paving
Constructed: Fall 1991
Max. Height: 18 ft.; 1:1 slope

Project: I-75 Weight Station
Location: Wildwood, Florida
Owner: Florida DOT
Engineer: Boyles Engineering
Contractor: DAB Construction
Constructed: Fall 1991
Max. Height: 12 ft.; 1:1 slope

Project: Maitland Pedestrian Overpass
Location: Maitland, Florida
Owner: Florida DOT
Engineer: Sverdup Corporation
Contractor: Martin Paving Company, Inc.
Constructed: Spring 1998
Max. Height: 21 ft.; 1.2:1 slope

Project: State Route 15 Realignment
Location: Debary, Florida
Owner: Florida DOT
Engineer: Greiner & Associates
Contractor: DeWitt Excavating
Constructed: Spring 1993
Max. Height: 30 ft.; 1:1 slope

GEORGIA

Project: Airport Expansion
Location: Atlanta, Georgia
Owner: Atlanta Hartsfield Authority
Engineer: Tensar Earth Technologies, Inc.
Contractor: Gilbert & Southern
Constructed: Fall 1992
Max. Height: 40 ft.; 1:1 slope

Project: I-285
Location: Atlanta, Georgia
Owner: Georgia DOT
Engineer: Georgia DOT
Contractor: C.W. Matthews
Constructed: Fall 1994
Max. Height: 35 ft.; 1.25:1 slope

IDAHO

Project: Kootenai Cutoff
Location: Sandpoint, Idaho
Owner: Idaho DOT
Engineer: Idaho DOT
Contractor: DeAtley Company Inc.
Constructed: Summer 1996
Max. Height: 8 ft.

ILLINOIS

Project: Peck Road
Location: Geneva, Illinois
Owner: Kane County, IL
Engineer: Terracon
Contractor: Plote Construction
Constructed: Spring 2000
Max. Height: 20 to 25 ft.; 2:1 slope

LOUISIANA

Project: I-10
Location: Baton Rouge, Louisiana
Owner: Louisiana DOT
Contractor: Angelo IAFRATI Construction
Constructed: Fall 1997
Max. Height: 19 ft.

KANSAS

Project: I-35 & Johnson Drive Exit
Location: Olathe, Kansas
Owner: Kansas DOT
Engineer: Howard, Needles, Tammen & Bergendoff
Contractor: Clarkson Construction Company
Constructed: Summer 1988
Max. Height: 15 ft.; 1:1 slope

Project: Route 150
Location: Topeka, Kansas
Owner: Missouri DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: Idecker, Inc.
Constructed: Winter 1998
Max. Height: 52 ft.; 1:2 slope

Project: I-135
Location: Salina, Kansas
Owner: Kansas DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: Clarkson Construction
Constructed: Summer 1999
Max. Height: 20 ft.; 2:1 slope

Project: US 50
Location: Kinsley, Kansas
Owner: Kansas DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: APAC
Constructed: 2000
Max. Height: 25 ft.; 1:5-1 slope

Project: Highway 156
Location: Ellsworth County, Kansas
Owner: Kansas DOT
Engineer: Tensar Earth Technologies, Inc.
Constructed: 2001
Max. Height: 9 ft.; 2:1 slope

KENTUCKY

Project: Cincinnati Airport
Location: Hebron, Kentucky
Owner: USPS
Engineer: QORE
Contractor: James H. Gray
Constructed: Winter 1999
Max. Height: 18 ft.

Project: U.S. Highway 23
Location: Prestonsburg, Kentucky
Owner: Kentucky DOT
Engineer: Bowser - Morner
Contractor: Bizzack Construction
Constructed: Spring 1992
Max. Height: 30 ft.; 1:1 slope

MAINE

Project: Poland Springs
Location: Poland Springs, Maine
Owner: Perrier Group of America
Engineer: Pinkham & Greer and Tensar Earth Technologies, Inc.
Contractor: White Brothers, Inc.
Constructed: Summer 1996
Max. Height: 37 ft.; 1:1 slope

MARYLAND

Project: Route 410
Location: Prince George City, Maryland
Owner: Maryland DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: Driggs Corp.
Constructed: Summer 1989
Max. Height: 48 ft.; 1.5:1 slope

Project: State Route 100
Location: Howard County
Owner: Maryland DOT
Engineer: KCI Technologies, Inc.
Contractor: Williams Construction
Constructed: Fall 1994
Max. Height: 50 ft; 1:1 slope

MASSACHUSETTS

Project: Pearl Street
Location: Braintree, Massachusetts
Owner: Mass Bay Transit Authority (MBTA)
Engineer: Tensar Earth Technologies, Inc.
Contractor: DeMatteo Construction
Constructed: Fall 1996
Max. Height: 25 ft.

MICHIGAN

Project: Highway M44
Location: Grand Rapids, Michigan
Owner: Michigan DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: K & R Contracting
Constructed: Summer 1991
Max. Height: 40 ft.; 1:2-1 slope

MINNESOTA

Project: Blake Road
Location: Edina, Minnesota
Owner: City of Edina
Engineer: STS Consultants
Contractor: C.S. McRossan
Constructed: Fall 1992
Max. Height: 10 ft.; 0.125:1 vegetated wall

Project: E-80 Cooper Train Loading
Location: Kellog, Minnesota
Owner: CPRR
Engineer: Tensar Earth Technologies, Inc. and CPRR
Contractor: Lunda Corporation
Constructed: Summer 1999
Max. Height: 22 ft.; 1:1 slope with temporary wall

MISSISSIPPI

Project: Maryland Hts. Subdivision
Location: Natchez, Mississippi
Owner: Natchez Housing Authority
Engineer: Jordan, Kaiser & Sessions
Contractor: Great River Stone
Constructed: Fall 1991
Max. Height: 45 ft. 1:1 slope

MISSOURI

Project: Elm Street Overpass
Location: St. Louis, Missouri
Owner: Missouri DOT
Engineer: Midwest Testing Engineer
Contractor: Fred Weber Contracting
Constructed: Fall 1992
Max. Height: 40 ft.; 50° Bridge Abutment

MONTANA

Project: Dickey Lake
Location: Lincoln Cty. , Montana
Owner: Montana Highway Department
Engineer: Midwest Highway Department
Constructed: Summer 1990
Max. Height: 60 ft.; 1:1 slope

NEBRASKA

Project: Davis Creek Dam
Location: Ord, Nebraska
Owner: Bureau of Reclamation
Engineer: Bureau of Reclamation
Contractor: Gilbert Central Corporation
Constructed: Summer 1990
Max. Height: 29 ft., 1:1 slope

NEW HAMPSHIRE

Project: Route 3A
Location: Hooksett, New Hampshire
Owner: New Hampshire DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: R.S. Audley
Constructed: Fall 1990
Max. Height: 40 ft. 1.25:1 slope

NEW MEXICO

Project: US 64
Location: Dulce, New Mexico
Owner: New Mexico DOT
Engineer: Highway Department
Contractor: Weeminuche Construction Authority
Constructed: Winter 1999
Max. Height: 22 ft.

Project: US 285
Location: New Mexico
Owner: New Mexico DOT
Engineer: Highway Department and Lewis Burger & Associates
Contractor: Nielsons Inc.
Constructed: Summer 1996
Max. Height: 40 ft.

NEW YORK

Project: Ithaca County Courthouse
Location: Ithaca, New York
Owner: Ithaca County
Engineer: Empire Soils
Constructed: Summer 1992
Max. Height: 10 ft. Vegetated Wall

Project: Route 174
Location: Ononadaga County, New York
Owner: New York DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: Sut-Kote Construction
Constructed: Summer 1994
Max. Height: 33 ft.; 1.25:1 slope

NORTH CAROLINA

Project: Bethlehem Road
Location: Rocky Mount, North Carolina
Owner: North Carolina DOT
Engineer: North Carolina DOT
Contractor: Barnhill Construction
Constructed: Spring 1991
Max. Height: 25 ft.; 1.1 slope

Project: Robbinsville Tellico Plains Road
Location: Robbinsville, North Carolina
Owner: FHWA
Engineer: FHWA
Contractor: Robbinsville Contracting
Constructed: Fall 1993
Max. Height: 40 ft.; 1.5:1 slope

Project: Route 74
Location: Graham City, North Carolina
Owner: North Carolina DOT
Engineer: North Carolina DOT
Contractor: Gilbert Southern
Constructed: Fall 1999

NORTH DAKOTA

Project: Teddy Roosevelt National Park, ND
Owner: National Park Service
Engineer: National Park Service
Constructed: Summer 1986
Max. Height: 20 ft.; 2:1 landslide repair

OHIO

Project: Ohio Turnpike
Location: Cleveland, Ohio
Owner: Ohio DOT
Constructed: Spring 2000
Max. Height: 60 ft.; 1:1 slope

PENNSYLVANIA

Project: Pennsylvania Turnpike
Location: Morgantown, Pennsylvania
Owner: Penn. Turnpike Authority
Engineer: GeoMechanics
Contractor: Stabler Construction
Constructed: Summer 1988
Max. Height: 35 ft.; 1:1 slope

SOUTH CAROLINA

Project: Highway 17
Location: North Charleston, South Carolina
Owner: South Carolina DOT
Engineer: F & ME
Contractor: Banks Construction
Constructed: Spring 1997
Max. Height: 20 ft.

Project: Route 5
Location: York County, South Carolina
Owner: South Carolina DOT
Engineer: Foundation and Material Engineers
Contractor: Jenkins Construction
Constructed: Fall 1990
Max. Height: 50 ft.; 2:1 landslide repair

TEXAS

Project: Combat Arms Training Facility
Location: Dyers AFB, Texas
Owner: Corps of Engineers
Engineer: Lockwood Greene
Constructed: Summer 1988
Max. Height: 24 ft.; 1:1 slope

Project: RM 2222
Location: Austin, Texas
Owner: Texas DOT
Engineer: Tensar Earth Technologies, Inc.
Contractor: Austin Filter Systems
Constructed: Spring 1990
Max. Height: 10 ft.; 1:1 Temporary Wall

VERMONT

Project: Gold Hill Road
Location: Montpelier, Vermont
Owner: City of Montpelier
Engineer: Pinkham Engineering Associates
Contractor: Morrill Construction
Constructed: Fall 1992
Max. Height: 75 ft.; 1:1 slope

Project: Route 30
Location: Townshed, Vermont
Owner: Vermont Agency of Transportation
Engineer: Vermont Agency of Transportation
Contractor: Miller Construction
Constructed: Summer 1991
Max. Height: 35 ft.; 1:1 slope

WASHINGTON

Project: 140th Avenue
Location: Kent, Washington
Owner: King County
Engineer: Hong West Associates and
Parsons Brinckerhoff
Contractor: Scarsella Brothers
Constructed: Fall 1999
Max. Height: 96 ft.; 2:1 slope

Project: State Route 20
Location: Concrete, Washington
Owner: Washington DOT
Engineer: Washington DOT
Constructed: Summer 1991
Max. Height: 60 ft.; 1:1 slope

WEST VIRGINIA

Project: Buckhannon Airport
Location: Buckhannon, West Virginia
Owner: Upshur City Airport
Engineer: HC Mutting & Chapman
Technical Group
Contractor: Kimberly Industries
Constructed: Winter 1996

Project: Highway 52
Location: McDowell County, West Virginia
Owner: West Virginia DOT
Engineer: West Virginia DOT
Contractor: Alan Stone
Constructed: Summer 1984
Max. Height: 35 ft.; 1.5:2 Landslide Repair

Project: Tri-State Airport
Location: Kenova, West Virginia
Owner: Tri-State Airport Authority
Engineer: Delta Engineers
Contractor: McCoy Construction
Constructed: Winter 1996

ONTARIO

Project: Highway 410
Location: Brampton, Ontario
Owner: Ministry of Transportation
Engineer: Ministry of Transportation
Constructed: 1983
Max. Height: 26 ft.; 1:1 slope

Project: Highway 407
Owner: Ministry of Transportation
Engineer: DS-Lea Associates, LTD
Contractor: Graham Bros. Construction
Constructed: Fall 1994
Max. Height: 37 ft.; 1:1 slope

5.0 ADVANTAGES & DISADVANTAGES

5.1 Advantages

There are several advantages associated with the use of a Sierra Slope Retention System versus reinforced MSE walls or cast-in-place walls. Some of the safety, performance, construction, aesthetic, and cost advantages are listed as follows:

- The Sierra Slope Retention System provides an attractive, natural appearance, with the use of vegetation as a facing element versus concrete units used in MSE wall systems.
- Sierra Slopes can be built at varying grades so that the entire RSS structure blends into existing grades. Concrete MSE wall structures create monolithic structures which can clash with the natural landscape.
- The Sierra System is a synergistic system, with consistent engineering through design, material manu facture, and construction. Agencies can specify Sierra with confidence knowing that the components will create a successful RSS structure.
- The Sierra Slope Retention System offers a significant in-place cost savings (up to 50%) over MSE walls (see Figure 6.1).
- A fairly wide range of backfill soils (i.e. typical highway embankment fills) have been successfully used with the Sierra System. Suitable quality backfill material can frequently be found on or near the construction site and thus need not be imported, potentially resulting in significant cost savings.
- Tensar Geogrids are inert and non-conductive; therefore, they provide excellent resistance to degradation in highway environments, particularly in the presence of decier salts and stray current environments.
- The Sierra System allows an Agency roadway design group greater flexibility in balancing cut and filling quantities on a job site.
- The deformation response of a Tensar Geogrid reinforced soil mass and the absence of concrete units provide a Sierra Slope with the flexibility to absorb unexpected large lateral and vertical deformations. This flexibility also makes the system ideal for use on sites with poor foundations or seismic activity.
- The vegetated Sierra surface provides better sound attenuation than smooth concrete surfaces.
- Construction is accelerated by the lack of need for forms or temporary bracing systems.
- Backfill placement and compaction proceeds quickly since no concrete facing elements are required.
- Slope construction does not require specialized contractors, skilled labor, or specialized equipment.
- Tensar Geogrids, drainage composites, and TRMs are relatively light and easy to handle.
- Post-construction maintenance costs such as cleaning and graffiti removal are avoided.

5.2 Possible Disadvantages

There are relatively few disadvantages associated with the Sierra Slope Retention System. Possible disadvantages are listed below along with methods to mitigate these potential disadvantages.

- The Sierra System may be new to Agency construction inspectors. Therefore, a precon-struction meeting of TET engineers, agency engineers and inspectors may be required to review the proper construction techniques.
- The Sierra System may be new to a contractor. Therefore, site assistance, in addition to that routinely provided on projects, may be required to educate the labor force on the proper construction technique.
- The Sierra System offers the option of a vegetation facing system that may require plant selection and landscape design aspects which are unfamiliar to some engineers or agencies familiar with the MSE wall structures. TET has the necessary expertise to address these issues so that highway agencies can specify Sierra with confidence.

In summary, the Sierra Slope Retention System constructed in accordance with this design specification will provide low cost, reliable, safe, and durable structures. The advantages of this system far outweigh any potential disadvantages.

6.0 TYPICAL COSTS

Typically, the in-place cost of a Sierra Slope Retention System is quoted per unit area of vertical face projection (i.e., per sq ft).
This pricing includes:

- Engineering and construction drawings
- All structural geogrid, drainage composite, and erosion control system materials
- Installation of structural geogrids, drainage composite, and erosion control system
- Placement and compaction of reinforced backfill soils
- Material and installation costs of vegetation

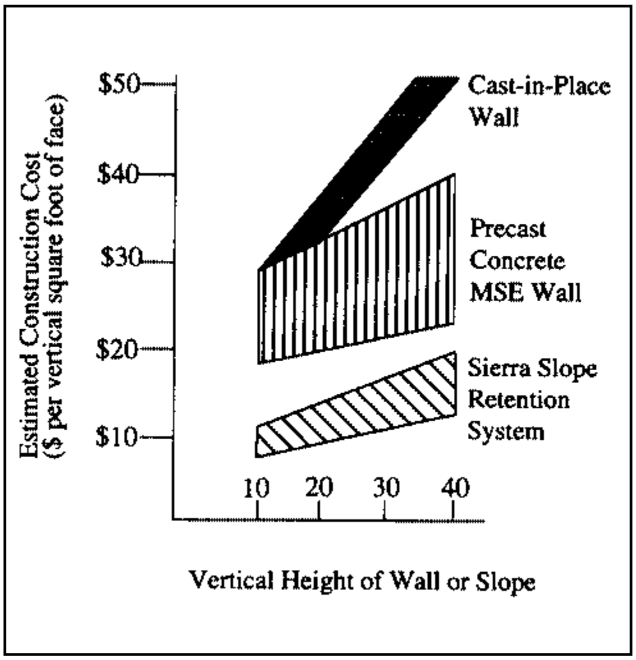


Figure 6.1 — Sierra Cost Comparison

7.0 SPECIFICATION FOR MECHANICALLY STABILIZED EARTH RETENTION SYSTEM

THIS SECTION IS WRITTEN IN CSI 3-PART FORMAT AND IN CSI PAGE FORMAT. NOTES TO THE SPECIFIER, SUCH AS THIS, ARE INDICATED WITH A ## SYMBOL AND MUST BE DELETED FROM THE FINAL SPECIFICATION. IT IS ASSUMED THAT THE GENERAL CONDITIONS BEING USED ARE AIA A201-87. SECTION NUMBERS ARE FROM THE 1995 EDITION OF MASTER FORMAT.

FOR THE MOST RECENT VERSION OF THIS SECTION, PLEASE VISIT OUR WEB SITE AT WWW.TENSARCORP.COM.

7.1 General

7.1.1 Summary
Section includes furnishing and testing materials, and the design and construction of a Mechanically Stabilized Earth (MSE) slope retention system.
Work consists of:

1. Furnishing structural geogrid reinforcement, drainage composite, and erosion control system as shown on the construction drawings.
2. Storing, cutting, and placing structural geogrid reinforcement, drainage composite, and erosion control system as specified herein and as shown on the construction drawings.
3. Furnishing sealed design calculations and construction drawings for MSE slope; providing supplier representatives for pre-construction meeting with the Contractor and Engineer.
4. Excavation, placement, and compaction of reinforced fill and backfill material as specified herein and as shown on the construction drawings.

EDIT LIST BELOW TO CONFIRM PROJECT REQUIREMENTS. VERIFY SECTION NUMBERS AND TITLES.

7.1.1.1 Related Sections
A. Section 2200 – Site Preparation
B. Section 02300 – Earthwork

7.1.1.2 Alternates
A. Geotextile materials will not be considered as an alternate to geogrid materials. Geotextile may be used to provide separation, filtration, or drainage; however, no structural contribution will be attributed to the geotextile.

B. Alternate geogrid materials shall not be used unless submitted to the Engineer and approved in writing by the Engineer at least 7 days prior to the bid letting. The Engineer shall have absolute authority to reject or accept alternate materials based on the requirements of this Section and the Engineer's judgment. Polyester geogrids, whether coated or uncoated, will not be approved for use in calcareous, alkaline, or highly acidic environments, including lime-treated or cement-treated soils, crushed lime rock, or soils potentially exposed to leachate from cement, lime, or de-icing salts. In no case shall polyester geogrids be used in soils with a pH > 9. In order to be considered, submittal packages for alternate geogrid materials must include:

1. A list of 10 comparable projects that are similar in terms of size and application, are located in the United States, and where the results of using the specific alternate geogrid material can be verified after a minimum of 3 years of service life.
2. A sample of alternate geogrid material and certified specification sheets.
3. Recommended installation instructions.
4. An explanation of engineering techniques used and sample design drawings and calculations prepared and sealed by a Professional Engineer licensed in the applicable state.
5. Additional information as required by the Engineer.

7.1.2 References

DELETE REFERENCES NOT USED IN PART 7.2 OR PART 7.3.

A. American Society for Testing and Materials (ASTM)

D374-94	Test Methods for Thickness of Solid Electrical Insulation
D1388-96	Standard Test Method for Stiffness of Fabrics, Option A
D2455-96	Standard Test Method for Identification of Carboxylic Acids in Alkyd Resins
D4595-94	Standard Test Method of Tensile Properties of Geotextiles by the Wide-Width Strip Method
D4355-92	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultra-violet Light and Water (Xenon-Arc Type Apparatus)
D4603-96	Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer
D4716-95	Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products
D4759-92	Practice for Determining the Specification Conformance of Geosynthetics
D5262-97	Standard Test Method for Evaluating Unconfined Tensile Creep Behavior of Geosynthetics
D5818-95	Practice for Obtaining Samples of Geosynthetics from a Test Section for Assessment of Installation Damage
D 6637-01	Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Test Method
F904-91	Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials

B. Geosynthetic Research Institute (GRI)

GG2-87	Standard Test Method for Geogrid Junction Strength
GG4-91	Determination of the Long-Term Design Strength of Geogrids
GG5-91	Standard Test Method for "Geogrid Pullout"
GG7	Standard Test Method for Carboxyl End Group Content of Poly (Ethylene Terephthalate) (PET) Yarns
GG8	Determination of the Number Average Molecular Weight of Poly(Ethylene Terephthalate) (PET) Yarns Based on a Relative Viscosity Value

C. U.S. Federal Highway Administration (U.S. FHWA)

FHWA NHI-00-043
Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines (Demonstration Project 82)

FHWA NHI-00-044
Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes

D. U.S. Environmental Protection Agency (U.S. EPA)

EPA 9090	Compatibility Test for Wastes and Membrane Liners

E. U.S. Army Corps of Engineers (USACE)
Draft Specification for Grid Aperture Stability by In-Plane Rotation

7.1.3 Definitions

Structural Geogrid - A structural geogrid is formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth and function primarily as reinforcement.

7.1.4 Submittals

A. The Contractor shall submit 6 sets of detailed design calculations, construction drawings, and shop drawings for approval at least 30 days prior to the beginning of construction. The calculations and drawings shall be prepared and sealed by a Professional Engineer, licensed in the State. Upon approval, the Engineer will make available 2 sets of the drawings to the Contractor. The Contractor shall obtain the approved drawings prior to commencing construction.

B. Submit geogrid product samples approximately 4 in. x 7 in. or larger and consisting of at least 4 entire apertures.

C. Submit Manufacturer's installation instructions and general recommendations.

7.1.5 Quality Assurance

A. Qualifications - The Engineer's approval of the system and the supplier will be based upon the following considerations:
   1. The geogrid reinforcement has been reviewed and approved for use.
   2. The supplier has a large enough operation and the necessary experience to supply and support the construction on a timely basis.
   3. Past experience in the design and construction of at least 10 projects of a similar magnitude of the proposed system can be documented.

B. The design shall be signed by a registered Professional Engineer who shall demonstrate a minimum Errors and Omissions insurance coverage of $1,000,000 by furnishing the Engineer with a current certificate of insurance.

C. Pre-Construction Conference - Prior to the installation of the geogrid, the Contractor shall arrange a meeting at the site with the geogrid material supplier and, where applicable, the geogrid installer. The Owner and the Engineer shall be notified at least 3 days in advance of the time of the meeting. The representative of the geogrid supplier shall be available on an "as-needed" basis during construction.

7.1.6 Delivery, Storage & Handling

Storage and Protection

A. Prevent excessive mud, wet concrete, epoxy, or other deleterious materials from coming in contact with and affixing to the geogrid materials.
B. Store at temperatures above -20° F (-29° C).
C. Rolled materials may be laid flat or stood on end.

7.2 PRODUCTS

7.2.1 Manufacturers

VERIFY SECTION NUMBERS AND TITLES

A. Acceptable Suppliers - A supplier or their representative must request, in writing 60 days prior to the bid date, to be placed on the approved supplier list. An approved source is The Tensar Corporation, Morrow, GA or their designated representative.

B. Substitutions - See Section 01600 and sub-part 7.1.1.2 of this Section.

7.2.2 Materials

THE PLANS SHOULD INDICATE WHERE GEOGRID TYPE(S) IS/ARE TO BE USED.

7.2.2.1 Structural Geogrid

The required physical and mechanical properties of geogrid reinforcement shall be as shown on the plans or established in writing by the Engineer at least 30 days prior to the bid.

A. **Primary Geogrid** - The primary geogrid, identified as types P1, P2, P3, and P4 shall provide the following allowable tensile properties:

LOAD CAPACITY

Property	Method	Primary Reinforcement Types P1	P2	P3	P4
True Initial Modulus, lbs/ft	ASTM D6637*	65,110	107,950	120,000	161,070
Tensile Strength @ 5% Strain, lbs/ft	ASTM D6637*	2,130	3,560	3,980	5,140
Long Term (T_a), lbs/ft**					
w/ sand, silt, and clay		2,000	3,100	4,100	5,140
w/ 3/4 minus angular aggregate		1,950	3,010	3,990	5,000
w/ 1-1/2 minus angular aggregate		1,910	2,960	3,920	4,910

INTEGRITY OF PRODUCT STRUCTURE

Property	Method	Primary Reinforcement Types P1	P2	P3	P4
Junction Strength, lbs/ft	GRI:GG2-87 @ 10%/min.	4,520	7,200	9,250	10,970

*The tensile strength at 2 percent and 5 percent strain shall be determined with this test conducted without artificially deforming test materials under load before measuring such resistance or employing an artificial secant or offset tangent basis of measurement so as to overstate tensile properties.

**Where: $T_a = \dfrac{T_{ULT}}{RF_{CR} \times RF_{ID} \times RF_D}$

1. T_{ULT} - Ultimate Tensile Strength shall be the minimum average roll value ultimate tensile strength as tested per ASTM D6637. This test shall be conducted without artificially deforming test materials under load before measuring such resistance or employing an artificial secant or offset tangent basis of measurement so as to over state tensile properties.

2. RF_{CR} - The Reduction Factor for Creep is the ratio of T_{ULT} divided by the creep-limited strength determined in accordance with ASTM D5262-97. Long-term tensile-strain-time behavior of the reinforcement shall be determined from controlled laboratory testing conducted for a minimum duration of 10,000 hours. The requirement for the minimum creep test period may be waived for a new product if it can be demonstrated that is sufficiently similar to a proven 10,000 creep tested product of a similar nature. When these conditions are met, creep testing shall be conducted for at least 1,000 hours and the results compared to the similar product tested for 10,000 hours. The 1,000-hour creep curves must pattern very closely to the 1,000-hour porting of the similar product to demonstrate equivalency. Creep test data at a given temperature may be extrapolated over time by one order of magnitude. Accelerated testing is required to extrapolate 10,000-hour creep data to a 75-year design life. Procedures for test acceleration are discussed in GRI-GG4. Creep testing is required on representative samples of the finished product and not a single component of the geogrid (e.g., fiber and/or yarn). The ultimate strength used in this calculation shall be that of the roll used in the testing and not the MARV for the product. Creep rupture testing, that has been performed through the use of alternative techniques (e.g., stepped Isothermal Method), must be supported with creep data conducted for a minimum of 10,000 hours at 20° C.

   In no event shall the minimum value of FS_{CR} be less than:

PVC-coated PET geogrid	1.75
Acrylic-coated PET geogrid	1.75
HDPE uniaxial geogrid	2.15
PP biaxial geogrid	4.00

3. RF_{ID} - The Reduction Factor for Installation Damage is the ratio of the virgin reinforcement T_{ULT} divided by the T_{ULT} of a sample of the same material recovered from an installation damage test. Tests shall be conducted using the actual backfill from the project in accordance with GRI-GG4. However, in lieu of such testing, the Manufacturer may supply test results from other backfill soils if such soils can be shown to result in more severe construction damage than the proposed backfill. T_{ULT} shall be determined in accordance with ASTM D6637-01 and sample recovery shall be consistent with ASTM D5818-95.

4. RF_D - Reduction Factor for Durability/Aging is the combined partial factor for potential chemical and biological degradation. RF_D shall be determined from polymer specific (HDPE and PP as identified by their mechanical properties, and PET as identified by CEG number and number average molecular weight, M_n) durability testing covering the range of expected soil environments. Polyolefin geogrids can

be used in a pH range from 2 to 12, and polyester geogrids can be used within a pH range of greater than 3 and less than 9.

The minimum Reduction Factor for Durability/Aging for HDPE and PP shall be 1.0. The minimum reduction factors for PET geosynthetics are as follows:

	Reinforced & Retained Fill		
Product	**3 < pH = 5**	**5 < pH < 8**	**8 = pH < 9**
Polyester geogrids Mn < 20,000; 40 < CEG < 50	2.0	1.6	2.0
Polyester geogrids Mn > 25,000; CEG < 30	1.3	1.15	1.3

5. For soils of potential concern, as presented below (modified soils shall include lime stabilized soil, cement stabilized soil, or concrete), only polymers listed as "no effect" shall be used within or adjacent to (3 feet shortest measurable distance) these soil environments (Ref: Table 8, FHWA NHI-00-044).

Soil Environment	PETP	PE	PP
Acid Sulfate Soils	NE	NE	?
Organic Soils	NE	NE	NE
Saline Soils, pH < 9	NE	NE	NE
Calcareous Soils	?	NE	NE
Modified Soils/Lime, Cement	?	NE	NE
Alkaline Soils, pH > 9	?	NE	NE
Acidic Soils, pH > 3	?	NE	NE
Soils with Transition Metals	NE	?	?

NE = No Effect
? = Questionable use, exposure tests required

6. C_i - Soil Interaction Coefficient value shall be determined from long-term effective stress pullout tests per GRI-GG5, unless the junction creep testing of the geogrid is used to determine T_a. The C_i value is determined as follows:

$$C_i = \frac{F}{2\ L\ \sigma_N \tan \phi}$$

Where:
F = Pullout force (lbs/ft), per GRI-GG5
L = Geogrid Embedment Length in Test (ft)
σ_N = Effective Normal Stress (psf)
ϕ = Effective Soil Friction Angle, Degrees

B. **Secondary Geogrid** - The secondary geogrid, identified as Types S1 and S2, shall meet the following physical property requirements:

LOAD CAPACITY

		Secondary Reinforcement Types	
Property	**Method**	**S1**	**S2**
Tensile Strength*			
@ 2% Strain, lbs/ft*	ASTM D6637	450	600
@ 5% Strain, lbs/ft*	ASTM D6637	920	1,340

INTEGRITY OF PRODUCT STRUCTURE

		Secondary Reinforcement Types	
Property	**Method**	**S1**	**S2**
Junction Efficiency, % of Ultimate Tensile Strength	GRI-GG2-87 @ 10%/min	93	93
Flexural Stiffness* mg-cm	ASTM D1388, Option A	250,000	750,000
Aperture Stability**	Corps of Engineers	3.2	6.5

Unless noted otherwise, values shown are for the cross machine direction and represent minimum average roll values with the exception that Flexural Stiffness, which is determined in the machine direction and represents typical values. The tensile strength at 2 percent and 5 percent strain shall be determined with this test conducted without artificially deforming test materials under load before measuring such resistance or employing an artificial secant or offset tangent basis of measurement so as to overstate tensile properties.

* Bending resistance values determined in the machine direction using specimen dimensions of 864 millimeters in length by 1 aperture in width.

**Resistance to in-plane rotation movement measured by applying a 20 kg-cm moment to the central junction of a 9-inch by 9-inch specimen restrained at its perimeter and measured in units of kg-cm/deg.

7.2.2.2 Geosynthetic Drainage Composite

A. The drainage composite shall consist of geotextile bonded to both sides of a polyethylene net structure. Drainage products manufactured with a cuspated core shall not be acceptable.
B. The minimum allowable transmissivity as per ASTM D4716-95 shall be equal to or greater than 1.5 gal. per min. per ft. of width at a confining pressure of 10,000 lbs. per sq. ft. for a gradient of 1.0.
C. The minimum allowable peel strength of the geotextile from the geonet as per ASTM F904-91 shall be equal to or greater than 250 gm. per in. of width.

7.2.2.3 Erosion Control System

A. The erosion control system shall consist of a combination of long-term nondegradable TRM, geogrid, SierraScape facing element, and/or geotextile.

B. The erosion control system can vary based on soil types, slope angle, climate, and vegetation requirements. Supplier shall provide specific erosion control system design for approval by Agency on a job-by-job basis.

7.3 Execution

7.3.1 Examination

The Contractor shall check the geogrid upon delivery to verify that the proper material has been received. The geogrid shall be inspected by the Contractor to be free of flaws or damage occurring during manufacturing, shipping, or handling.

7.3.2 Preparation

The subgrade soil shall be prepared as indicated on the construction drawings or as directed by the Engineer. Foundation soil shall be excavated to the lines and grades as shown on the drawings or as directed by the Engineer. Overexcavated areas shall be filled with compacted backfill material.

7.3.3 Installation

A. Geogrid shall be laid at the proper elevation and orientation as shown on the construction drawings or as directed by the Engineer. Where percent coverage and truncation options are shown on the plans, alternate layers of primary UX Geogrid reinforcement shall be placed in a staggered pattern such that the layer above is placed with the center line of the geogrid in alignment with the centerline of the open space below. The maximum horizontal spacing between geogrids where percent coverage design alternates are employed shall be 4 to 6 inches. Correct orientation (roll direction) of the geogrid shall be verified by the Contractor. Geogrid may be temporarily secured in place with staples, pins, sand bags, or backfill as required by fill properties, fill placement procedures, or weather conditions, or as directed by the Engineer.

B. Geogrid soil reinforcement shall be connected/spliced when required to provide continuity of tensile resistance. Geogrids manufactured using polyolefins (e.g., HDPE and PP) shall be connected with a mechanical polymer bar. Geogrids manufactured of polyester shall be connected by sewing with Kevlar sewing thread perpendicular to the direction of loading at the ends of the materials.

C. Overlap connections may be used if the Contractor provides the Engineer independent test documentation which demonstrates that the load/deformation characteristics of the overlap of geogrid materials is equal to or exceeds those of the geogrid. The minimum overlap shall be 5 feet.

7.3.4 Fill Placement Over the Geogrid

VERIFY SECTION NUMBERS AND TITLES

A. Backfill material shall be placed in lifts and compacted as directed under Section 02300. Backfill shall be placed, spread, and compacted in such a manner that minimizes the development of wrinkles in and/or movement of the geogrid.

B. Tracked construction equipment shall not be operated directly on the geogrid. A minimum fill thickness of 6 inches is required prior to operation of tracked vehicles over the geogrid. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid. Rubber-tired equipment may pass at slow speeds (less than 10 mph) over extruded polyolefin geogrid reinforcement placed atop competent substrate. Sudden braking and sharp turning shall be avoided. Rubber-tired equipment shall not pass over polyester geogrid reinforcement. A minimum fill thickness of 6 inches is required prior to operation of rubber-tired equipment over polyester geogrid reinforcement.

7.3.5 Repair

A. Any geogrid damaged during installation shall be replaced by the Contractor at no additional cost to the Owner.

B. Coated geogrids shall not be used if the coating is torn, shedding, cracked, punctured, flawed or cut, unless a repair procedure is carried out as approved by the Engineer. The repair procedure shall include placing a suitable patch over the defective area or applying a coating solution identical to the original coating.

7.3.6 Protection

Follow the Manufacturer's recommendations regarding protection from exposure to sunlight.

8.0 SIERRA INSTALLATION GUIDE

Step 1 – Site Excavation. The site should be properly excavated to the lines and grades as shown on the construction drawings or as directed by the Engineer. Excavation should include removal of soil to ensure firm foundation and benching the back cut into competent soils to improve stability.

Step 2 – Internal Drainage. Drainage composite shall be rolled out onto the benched back cut prior to installation of geogrid and fill placement. Roll drainage composite up the back cut until approximately 2/3 of the reinforced slope height is reached. Drainage composite is typically placed to achieve 30% coverage unless design considerations dictate otherwise. The drainage composite is normally terminated against a slotted drain pipe within geotextile wrapped gravel (See Figure 8.1).

Step 3 – Geogrid Lengths and Types. Two types of Tensar structural geogrids are used in Sierra Slopes: Uniaxial (UX) and Biaxial (BX). These terms refer to the number of directions in which a punched sheet of polymer has been drawn in the manufacturing process. Uniaxial has one direction of draw and biaxial has two. (Figure 8.2)

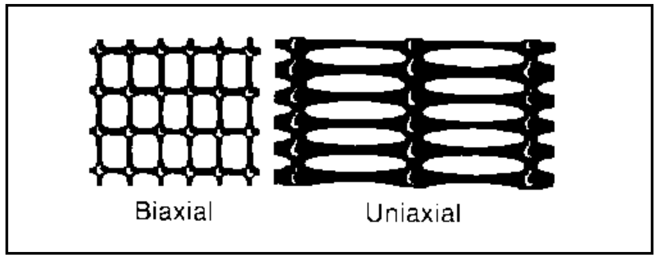


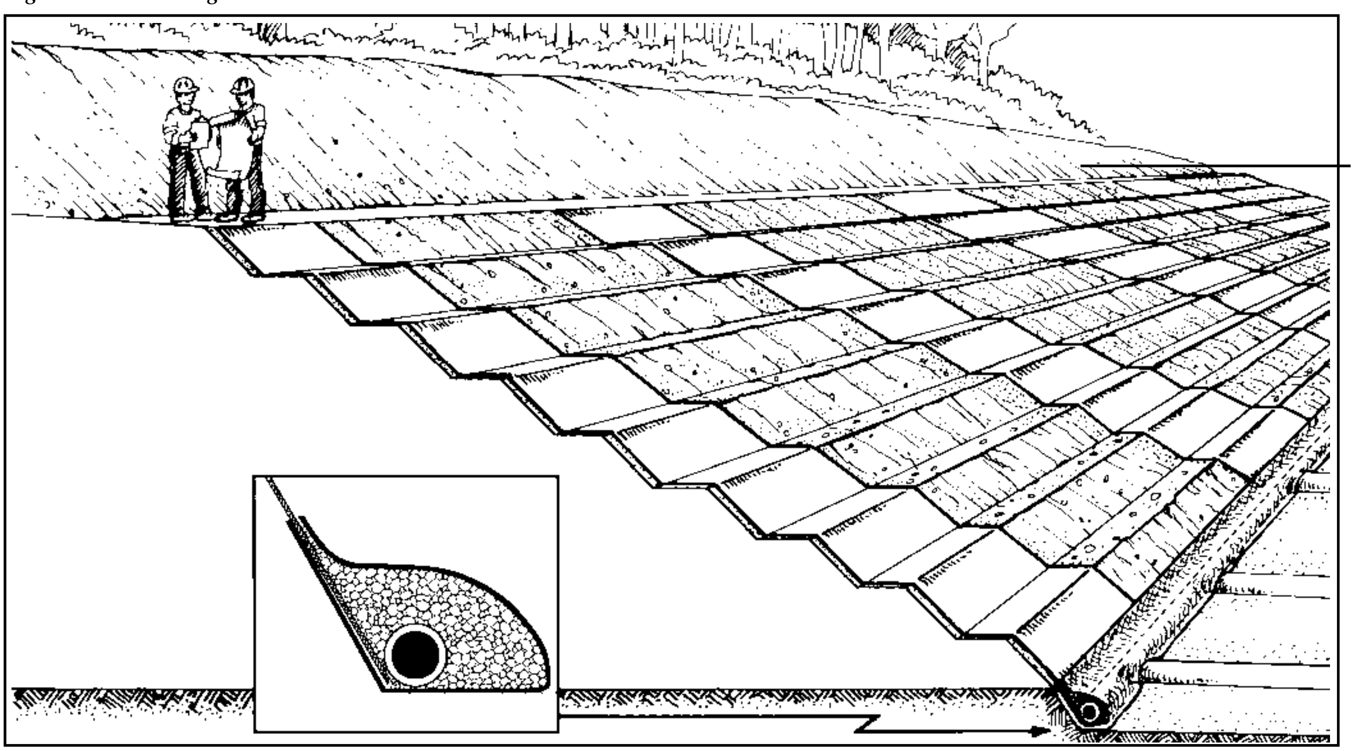
Figure 8.2 — Types of Tensar Geogrid

For construction using Tensar UX Geogrids, the longitudinal roll direction must be oriented perpendicular to the slope face. In construction using Tensar BX Geogrids, the transverse roll direction is typically oriented perpendicular to the slope face. A simple check of Tensar UX Geogrid orientation is to ensure that the longer of the two geogrid aperture axes is perpendicular to the slope face alignment.

Primary reinforcement lengths are typically longer than secondary reinforcement lengths and may vary with location and elevation. Generally, secondary reinforcement length is the same throughout the slope.

Simple procedures can minimize the potential installation of incorrect geogrid lengths. For construction expedience, the geogrid reinforcement is often cut to length in a staging area. These cut lengths are then stockpiled and marked or tagged to indicate their length.

Figure 8.1 — Benching the Backcut



A potential problem can arise on projects where two different geogrids are utilized. For instance, different grades of Tensar UX Geogrids may look very much alike. Confusion between different structural geogrids can be eliminated by proper separation during stockpiling, precutting, and tagging operations. The geogrids may also be color coded with spray paint.

Step 4 – Geogrid Placement. Geogrid layers should extend back from the slope face to the distance specified and placed at the elevations shown on the construction drawings. (Figure 8.3) Adjacent geogrid strips should be butted together side-by-side without overlap (Note: A small overlap may be specified for wrap-around construction of the slope face). Some designs may call for partial coverage requiring a space between geogrid strips. Soil is usually piled on the ends of the strips or use of "U" shaped ground anchors to avoid movement of the geogrids during fill placement.

Care must be taken to prevent slack from becoming trapped within the geogrid as fill is placed. Tracked construction equipment must not be operated directly upon the geogrid. Rubber-tired equipment may pass over the geogrid at slow speeds. Sudden braking and sharp turning that can displace geogrids from their intended positions should be avoided.

Overlapping geogrids on convex curves of slope alignments should be separated by at least three inches of compacted slope fill. Geogrids on concave curves may simply diverge from the slope face as shown in Figure 8.4.

Step 5 – Common Fill and Topsoil Fill Placement. Fill can be placed and spread directly upon the geogrids. Compact the soil to specifications using standard equipment and procedures (Figure 8.5 and 8.6). Lift thickness should be great enough to ensure that sheepsfoot will not come in direct contact with the geogrid.

Topsoil is typically placed up to a depth 1–2 feet back from the slope face during the fill placement process. This insures that an adequate layer of topsoil is in place to support vegetation and be reinforced by the geogrid reinforcement.

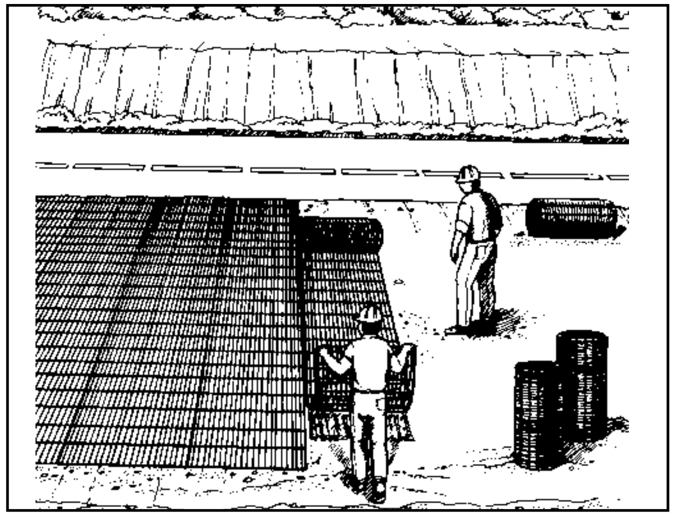


Figure 8.3 — Placing Geogrid Strips

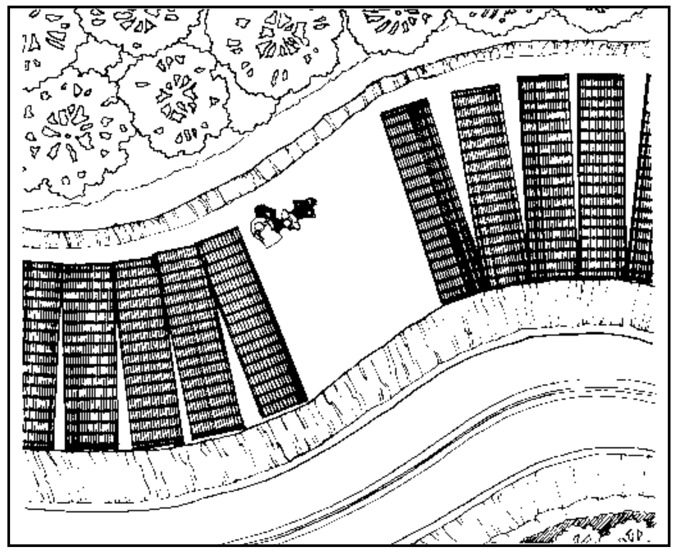


Figure 8.4 — Placing Geogrid on Curves

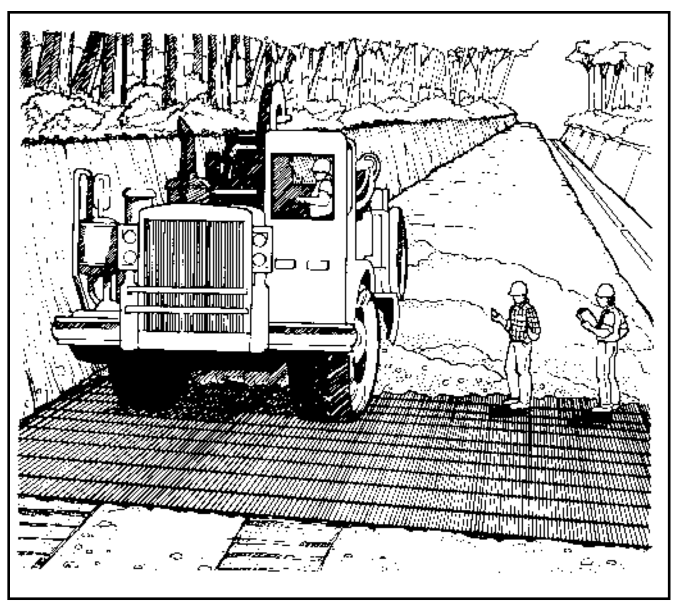


Figure 8.5 — Placing Fill

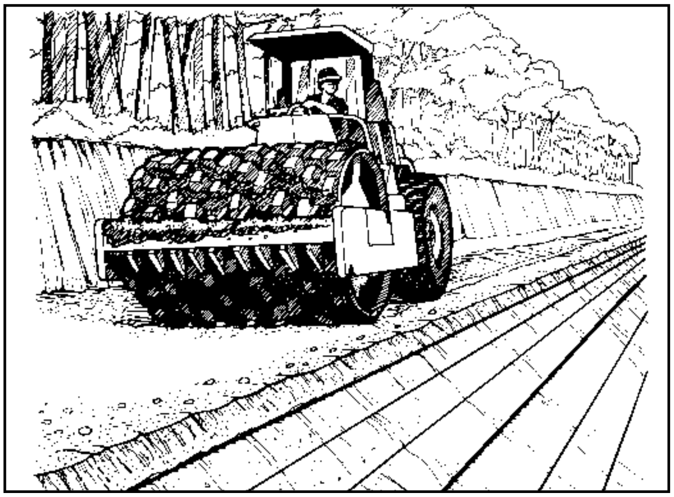


Figure 8.6 — Compaction

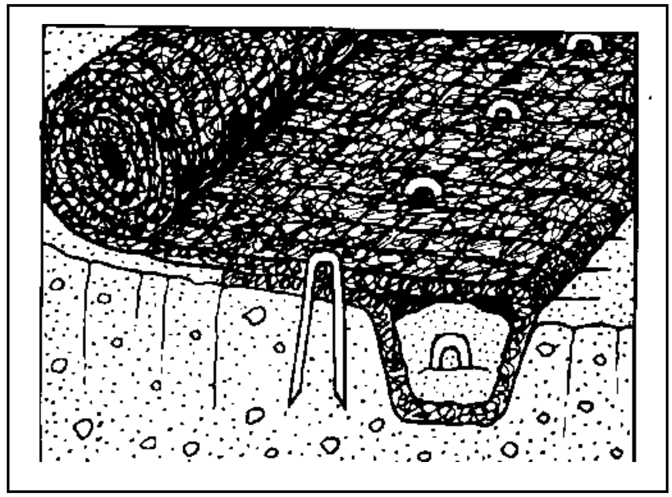


Figure 8.7 — Burial of Transverse Terminal Ends (6" x 12")

During construction, soil may cascade over the slope edge and begin to pile up on the slope face. This soil should be removed to insure a consistent grade is maintained. Failure to remove this soil will result in localized sliding of the slope face. Typically, the slope face will be overbuilt 2–4 feet to achieve adequate compaction. The slope face can be cut back to final grade by the use of a back hoe with a smooth bucket. Care should be taken to insure that grid layers are exposed at the face of the slope indicating that geogrid reinforcement extends completely to the slope face.

The final treatment of the slope face may require compaction to create a relatively smooth surface to ensure adequate performance of the erosion control system.

Step 6 – Erosion Control System. The erosion control system is often constructed at the completion of the slope after all other construction is completed. This method is usually limited to slopes that are 45° or flatter and do not require a wrap technique. Placement of a long-term non-degradable erosion blanket can be done quickly and easily with a minimum of hand labor. Beginning at the crest of the slope bury the transverse terminal end of the blanket to secure and prevent erosive water flow underneath (Figure 8.7). Unroll blanket from top of the slope face and secure with 8 in. - 12 in. "U" shape metal staples. Blanket should lay flat. DO NOT PULL BLANKET TAUT. Pulling taut may cause blanket to bridge depressions in the surface and allow erosion underneath. Refer to Manufacturer's Installation Guidelines for specific details. Temporary erosion control measures during and shortly after construction must be taken to ensure proper establishment. Water must be prevented from overtopping the slope crest and forming erosion ruts in the face of the slope. Design considerations must be taken to pipe or channel water away to the toe of the slope.

Wrapped Face System. Slopes steeper than 45°, landscaped slopes, and rock faced slopes will typically require a wrapped face system. SierraScape facing elements should typically be used for this purpose. TET's SierraScape System provides superior protection against surficial slope failure during and immediately following construction where vegetation is being established. In addition, SierraScape facing elements serve as forming devices to ensure a consistent slope angle and enhance compaction at the face. A typical wrapped-face system is shown in Figure 8.8. Other techniques using welded wire or boards may be used. Consult your manufacturer representative for details on these systems.

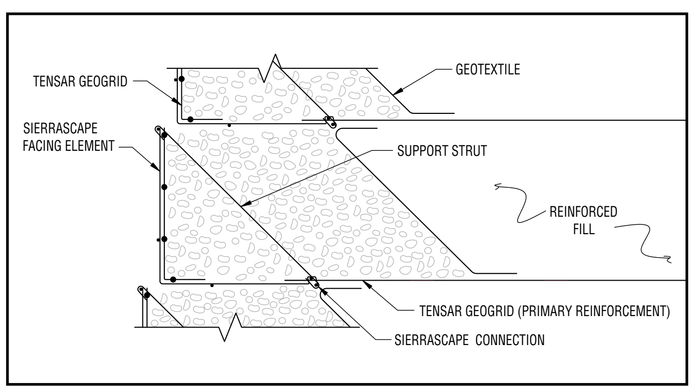


Figure 8.8 SierraScape System Detail

Step 7 - Vegetation Installation. The landscape design of a Sierra Slope will specify details on vegetation choices and installation. Common methods used for establishment of grass or wildflowers are to hydroseed, dry spread seed, or sod. Seed or sod is placed by these techniques on the prepared soil of the slope face and held in place by geogrids or long-term non-degradable erosion mattings. Landscaped or revegetated native slopes will typically require the use of containerized, balled and burlap, or bare root plantings. Planting holes are usually dug by hand using hand tools or hand-held mechanical augers. Care must be taken to ensure worker safety by the use of safety lines, ladders, and proper supervision.

9.0 MAINTENANCE & MOWING

Maintain slopes in accordance with owners specifications. Additional guidelines for mowing do's and don'ts are as follows[45]:

Mowing Operation Do's

- Avoid mowing slopes steeper than 2.5:1 with a regular mower unit.
- Mow slopes steeper than 2.5:1 with side mounted mower on a boom if the tractor unit remains on flatter surfaces while mowing.
- Operate side-mounted or boom mower units on the uphill side of the tractor to limit the possibility of overturning the tractor.
- Replace broken or lost chain guards to deflect debris immediately. Using flail-type mowers reduces the amount of debris thrown.
- Cover all v-belts, drive chains, and power takeoff shafts.
- Raise mowers when crossing driveways or roadways.
- Shut off power before checking any mower unit. Block a mower before changing, sharpening, or replacing a blade. Any blade being re-installed should be checked for cracks or damage that will lead to failure.
- Using flashing signals and slow-moving-vehicle signs on all mower tractors.
- Use signs to warn traffic, such as "Mowing Ahead, Mowing Area, Road Work Ahead" or similar legends. Signs should not be more than one to two miles ahead of the mowing. Signs saying "Mowing Next __ Miles" may be used in advance of the operation, but the distance limits should not be shorter than two miles nor longer than five miles.

Mowing Operation Dont's

- Mow too often. This wastes money, exposes mowing crews to traffic hazards more than needed, and can damage the vegetation.
- Mow at the wrong time. Good timing reduces the frequency of mowing required by cutting the vegetation in the right stage of growth.
- Mow too short. Leaving the proper height helps maintain the stand of vegetation and keeps small litter objects hidden.
- Mow steep slopes if you don't need to. Steep slope operations increase risk of mower accidents.
- Mow patterns inconsistently and mow a regular area incompletely. Drivers watch the pattern of a mowed area to help understand the safety of an area. Consistent mowing of similar areas helps drivers evaluate the safety of the roadway.
- Mow when wet. This is hard on equipment.
- Operate equipment carelessly and scar trees and shrubs. Mowing is tedious but care must be taken to avoid accidents and preserve valuable plantings.

APPENDIX A
REINFORCED FILL SOIL PARAMETERS

A.1 Gradation, Plasticity Index, and Chemical Composition

Gradation[9]: Recommended backfill requirements for MSE slopes per FHWA[4] are:

Sieve Size	Percent Passing
4 inch	100-75
No. 4	100-20
No. 40	0-60
No. 200	0-50

Definition of total and effective stress shear strength properties become more important as percent passing the No. 200 sieve increases. Likewise, drainage and filtration design are more critical.

Plasticity Index[9]. PI ≤ 20 (AASHTO T-90) and a magnesium sulfate soundness loss < 30% after 4 cycles is required.

Note that fill materials outside of these graduation and plasticity index requirements have been used successfully[9,44]. Performance monitoring is recommended if fill soils fall outside of the requirements listed above.

Chemical Composition. The chemical composition of the fill and retained soils should be assessed for affect on durability of reinforcement (pH, chlorides, oxidation agents, etc.). Soils with pH > 12 or with pH ≤ 3 should not be used in Sierra Slopes[12]. A pH range ≥ 3 to ≤ 9 is recommended. Specific supporting data should be required if pH > 9.

A.2 Soil Fill Design Properties

Shear Strength. Peak shear strength parameters should be used in the analysis[8]. Effective stress strength parameters (ϕ',c') should be used for granular soils with less than 15% passing the No. 200 sieve. Parameters should be determined using direct shear or consolidated-drained (CD) triaxial tests.

For all other soils, peak effective stress and total stress strength parameters should be determined. These parameters should be used in the analysis to check stability immediately after construction and long-term. Use consolidated drained (CD) direct shear tests (sheared slowly enough for adequate sample drainage) or consolidated-undrained (CU) triaxial tests with pore water pressures measured for determination of total stress parameters.

It is recommended that shear strength testing be conducted. However, use of assumed shear values based on agency guidelines and experience may be acceptable for some projects. Verification of site soil type(s) should be made after excavation is made or borrow pit identified, as applicable.

Unit Weights. Dry unit weight for compaction control, moist unit weight for analysis, and saturated unit weight for analysis (where applicable) should be determined for the fill soil.

A.3 Topsoil

Successful vegetation establishment and survival is a key component in the long-term design of an MSE slope. Consequently, based on local conditions, placement of a topsoil may be required. Topsoil qualities can vary widely but typically a topsoil fill classified in the AASHTO A-2-6 to A-2-7 ranges can be used. A minimum of 2% organic matter is also valuable to successfully support plant life.

APPENDIX B
VEGETATION AND EROSION CONTROL SYSTEM SELECTION GUIDELINES

B.1 Vegetation Facing Selection

A key feature of the Sierra System is the flexibility it offers the designer to create an attractive and natural facing. Selection of the vegetation component is an integral part of the overall design of the erosion control system. Vegetation should be selected to blend with or accent existing site conditions. Slope angle should also be considered when the vegetation selection is made. There are four primary types of vegetation facings available. Table B.1 below describes these options and typical sites where they can be used.

B.2 Erosion Control System Selection

After the desired slope angle and vegetation selection are made an erosion control system can be designed. The typical erosion control system will employ a biotechnical design. Engineering design techniques and horticulture experience are used to combine geosynthetic materials and vegetation to create a stable slope facing system. These options can be divided into three groups based on slope angle. Table B.2 on the following page describes the most common erosion control products and vegetation options used on Sierra Slopes.

Table B.1
Recommended Maximum Slope Angle and Typical Sites
For Vegetation used on Sierra Slopes

Type of Vegetative Facing	Slope Angle	Recommended Typical Site
Grass or Crown Vetch- Applied by hydroseeding or rotary spreaders and used in conjunction with an erosion control mat or blanket.	1/2:1 or flatter	- Downslope roadway embankment - Backside or low visibility side of development - Rural site
Wildflower- Applied by hydroseeding or rotary spreaders and used in conjunction with an erosion control mat or blanket.	1:1 or flatter	- Upslope roadway embankment - Native landscape setting - Suburban setting - Rural site
Landscaped Slope- A designed ornamental planting using selected shrubs and ground covers in a mulched bed. The plants are generally hand planted with a landscape fabric employed to control erosion and reduce weed infiltration.	1:1 or flatter	- Urban or suburban road widening - Property entrance or frontage - Homeowners slope
Native Planting- A revegetated slope that combines naturally occurring ground cover, grasses, shrubs, and trees. Usually combines both seeding and hand planting techniques.	1:1 or flatter	- Native rural landscape - Wetlands site - Arid mountain side - Reforested area

Table B.2
Erosion Control System Selection Guidelines

Slope Angles	Vegetation[1]	Erosion Control System Description
1:5:1 Flatter	**Grass, crown vetch or wildflower mix**	Excelsior Blanket Straw Blanket Geosynthetic Erosion Blanket
	Landscape slope planted shrubs in mulched bed	Geotextile wrapped face[2]
	Native planting seeded native grasses, ground covers, and planted shrubs or trees	Excelsior Blanket Geosynthetic Erosion Blanket
1:1 - 1:5:1	**Grass crown vetch or wildflower mix**	Geosynthetic Erosion Blanket
	Landscaped slope with planted shrubs in mulched bed	Geosynthetic wrapped face[2]
	Native planting using seeded native grasses, ground covers, and planted shrubs or trees	Geosynthetic Erosion Blanket
1/2:1 – 1:1	**Grass** sod held by geogrid wrap	Tensar BX Geogrid wrapped face with wire forms
	Grass and crown vetch seeded mix	Geotextile and geogrid wrapped face with wire forms
	Grass seeded mix applied through erosion blanket	Geosynthetic Erosion Blanket and Tensar BX Geogrid wrap with wire forms

1. General recommendations on vegetation options are outlined in Sierra Slope Facing Selection Manual.

2. Use a professional grade landscape fabric or 6 oz. (min.) needle-punched nonwoven geotextile.

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Tensar®

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TTN-Sierra-7.03

SIERRA®

SLOPE RETENTION SYSTEM

INSTALLATION GUIDE

Tensar®

INTERNATIONAL

Easier installation makes the Sierra® Slope Retention System a more affordable alternative to conventional retaining walls.

TENSAR® GEOGRIDS

The Sierra System owes its strength and durability to **Tensar Uniaxial (UX)** Geogrids, Tensar International Corporation's patented reinforcement geogrids. Due to their stiff interlocking capabilities, these geogrids stand the test of time, performing better than other commercially available geosynthetics. For more information, visit www.tensar-international.com.

Introduction

In worldwide use since 1982, the Sierra® Slope Retention System continues to be the premier reinforced soil slope (RSS) solution of choice among owners and developers, engineers, architects and contractors alike. Developed by Tensar International Corporation (Tensar), the world leader in geogrid technology and engineering ingenuity, Sierra Slopes ensure a combination of performance, economy and beauty that is unmatched by other types of earth retention systems.

The Sierra System is a complete and fully integrated Mechanically Stabilized Earth (MSE) System. Each of the system's components have been specifically designed and detailed to work together for optimum efficiency and performance. Furthermore, these components create a structural solution whose integrity and dependability have been proven in a variety of challenging site conditions such as the support of buildings and earthquake loadings.

The following steps provide a general guideline for installing the Sierra Slope Retention System. These steps will help you through standard installation procedures from your project's start to finish. If you are installing a Sierra Slope and require more detailed information, please refer to the project's installation instructions, the drawings within the contract bid documents or consult your local Tensar representative.

TOOLS REQUIRED

- Circular saw with masonry blade
- Sawhorses and plywood for constructing a worktable to cut the geogrids
- Steel pipe for unrolling geogrids on the worktable
- Steel "U" pins for securing geogrid to the ground
- Spray paint (one color for each type of geogrid, if more than one type of Tensar Geogrid is used)

SIERRA System Components

COMPONENT	FUNCTION
Tensar Uniaxial (UX) Geogrids	Primary reinforcement that internally reinforces structure and fill materials.
Tensar Biaxial (BX) Geogrids	Secondary reinforcement that ensures surficial stability of the slope structure.
Site-Specific Facing System	Provides aesthetic value by offering multiple facing options, including bioengineering.
Full Engineering and Construction Services	Detailing, design, construction services, drawings, quality control testing, construction installation.

Figure 1: Color coding the geogrid rolls.

1. Cutting Tensar Geogrids

- Color code the ends of the Tensar Geogrid rolls if more than one type of Uniaxial (UX) Geogrid is specified (Figure 1).
- Cut Tensar Geogrids to the lengths shown on the construction drawings (from the first rib to the last rib). Lengths shown on drawings do not include "fingers". Make the cut next to the heavy transverse ribs that span the width of the geogrid roll. Cut geogrids flush at the nearest transverse bar beyond the measured length (Figure 2).
- To easily cut geogrids, use a circular saw on a worktable (Figure 3).
- As geogrid lengths are cut, mark and tag them according to the length and type, and then stockpile them for later use.

  Note: The correct geogrid type and lengths must be used at each lift level according to the project's design.

2. Site Excavation & Drainage

- Excavate to the lines and grades shown on the construction drawings or as directed by the engineer.
- To improve stability, it is recommended that the sidehill embankments be benched into competent soil or rock (Figure 4, top of page 3).
- Use drainage composite as specified in the drawings, and install the drainage system according to the construction drawings (see Figure 4, inset top of page 3).

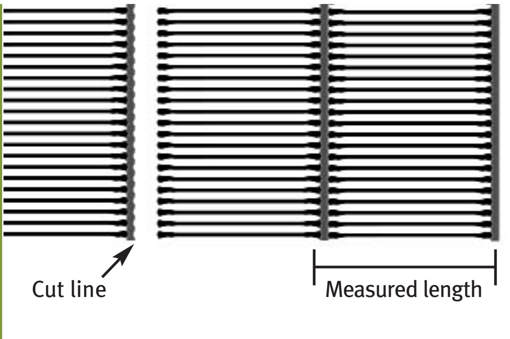


Figure 2: Cut geogrid.

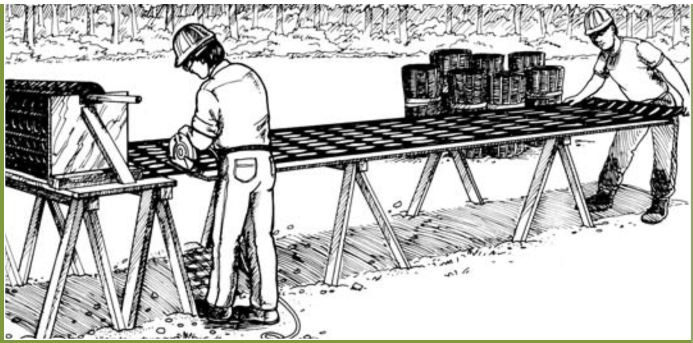


Figure 3: Cutting geogrid with a circular saw.

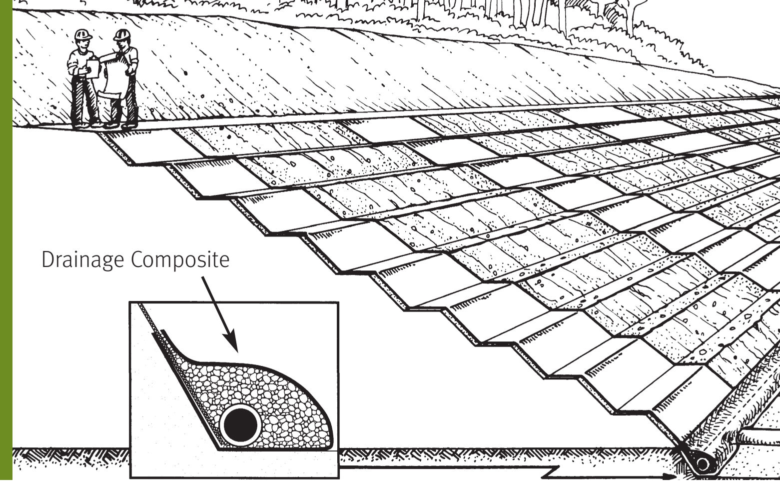


Figure 4: Benching the backcut and typical placement of drainage composite.

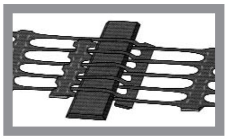
4. Primary Geogrid Placement

- Tensar UX Geogrids are most often used as "primary" reinforcement, and Tensar BX Geogrids are typically used as "secondary" or "surficial" reinforcement. UX Geogrids are supplied in roll widths of 4.3 ft (1.3 m). The use of BX Geogrids as surficial reinforcement is discussed in Section 6 of this guideline.
- Place geogrid rolls perpendicular to the slope (Figure 5) with the transverse bar end of the geogrid at the slope face.
- Geogrid strips should extend back from the slope face to the distance specified on the construction drawings and must be placed at the elevations shown on the construction drawings.
- Adjacent geogrid strips should be butted together side-by-side without overlap unless a gap between the strips is specified.

Note: A small covering may be specified for "wrap around" construction. Check construction drawings.

5. Fill Placement

- Short pieces of UX Geogrids can be spliced using flat polymer "bodkin" slats available from Tensar (shown right).



- Fill can be placed and spread directly upon the geogrids with rubber tired equipment (Figure 6). Keep speeds slow and avoid turns and stops on the geogrids. If needed, the geogrids can be secured into place to prevent movement during fill placement. Use pins, staples, sandbags, small piles of soil, etc. as anchors.
- Spread and level the soil (Figure 7). Do not drive tracked equipment on exposed geogrids.

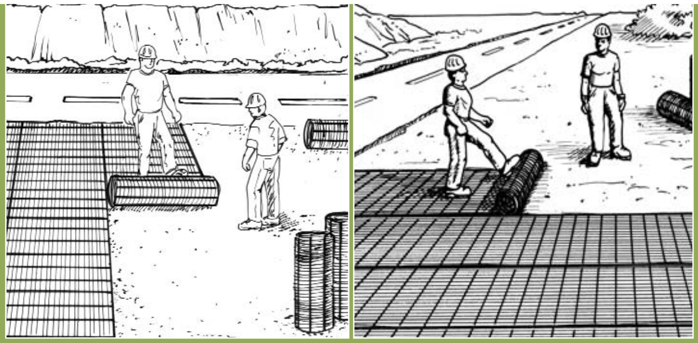


Figure 5: Unrolling and orienting the primary reinforcment UX geogrids.

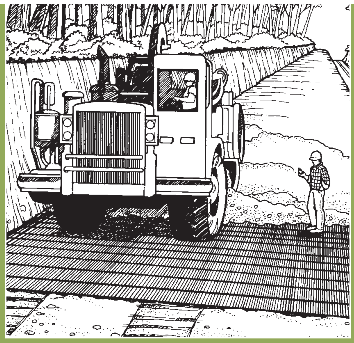


Figure 6: Place fill.

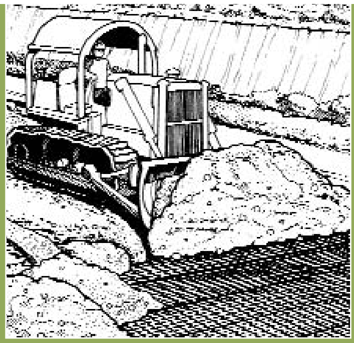


Figure 7: Spread and level fill.

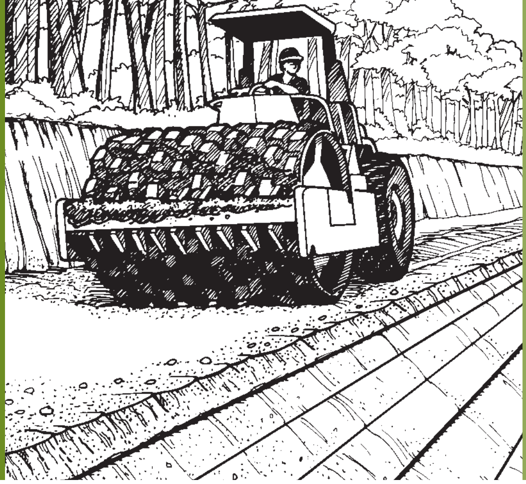


Figure 8: Compact fill.

6. Compaction

- Compact the soil to the specified density using standard compaction equipment and procedures (Figure 8). The lift thickness should be great enough to ensure that sheepsfoot cleats will not come in direct contact with the geogrid.
- For curved slope faces, the primary geogrids butt edge-to-edge at the slope face (unless shown otherwise on the construction drawings) and either fan out or overlap into the fill (Figure 9).

7. Surficial Reinforcement

- Embedments of BX Geogrids may be required to provide stability of the slope surface. Generally, the BX Geogrids will be unrolled parallel to the slope (Figure 10). Tensar BX Geogrids are supplied in roll widths of 9.8 ft (3 m) or 13.1 ft (4 m). The geogrid rolls may be cut to a specified width before unrolling.
- Fill can be spread directly upon the geogrids.
- Spread and level the fill. **Do not drive tracked equipment directly upon the exposed geogrids.**
- BX Geogrids may be cut to conform to horizontal curves.

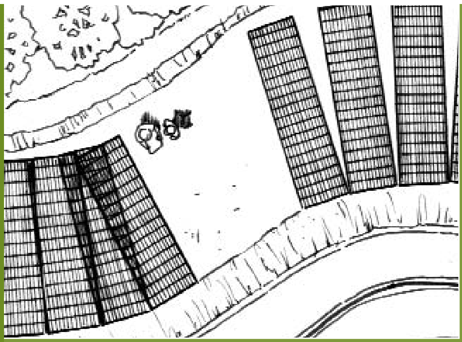


Figure 9: Placing geogrids on curves.

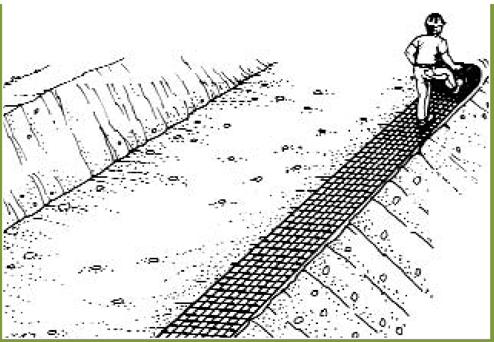


Figure 10: Installing BX Geogrid parallel to the slope.

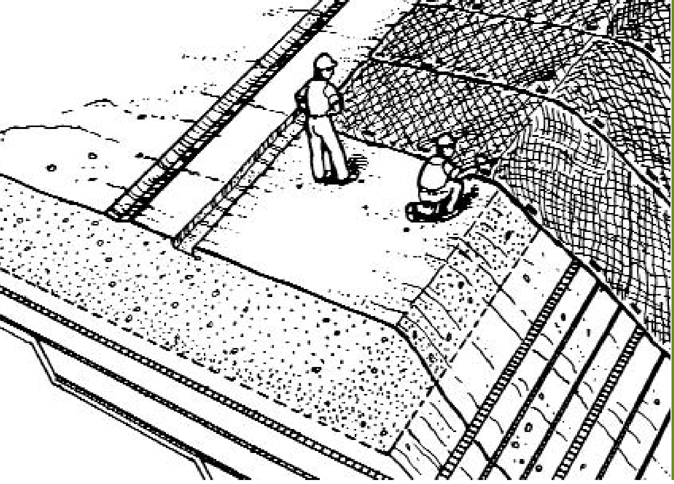
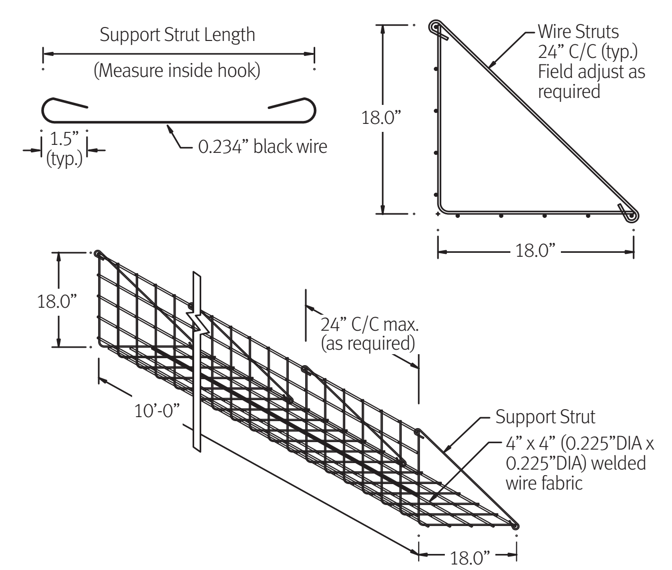


Figure 11: Installing turf reinforcement mat (TRM).

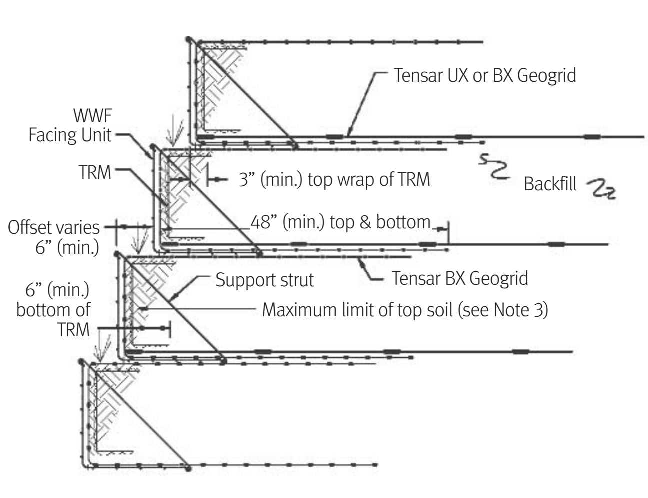
8. Erosion Control

- Grade to top of the completed slope to ensure that water runoff is directed away from the face of the new slope. Positive drainage must be provided so that water does not collect above or behind the reinforced soil.
- Place the North American Green® turf reinforcement mat (TRM) in position on the face of the slope and pin it in place (Figure 11).
- For steeper slopes, face angles greater than 1H:1V, a geogrid wrap around and form system may be used. Wire forms (Figure 12) can be utilized in conjunction with a BX Geogrid wrap (Figure 13) to aid in maintaining facing alignment.



Notes:
1. Facing to consist of prefabricated WWF 4" x 4" (0.225"DIA x 0.225"DIA) forms.
2. All forms and struts will be fabricated from black wire.
3. Overall length of wire forms is 10'-0". Effective construction width is 9'-8" with 4" overlapping at ends.

Figure 12: Welded-wire form facing unit detail.



Notes:
1. See welded wire form (WWF) facing unit detail for facing materials & dimensions.
2. All facing units shall be fabricated from black steel.
3. Topsoil shall be loamy sand and finer gradation with 10-15% organic content or material approved by a qualified landscape architect. Vegetation type shall be specified by a qualified landscape architect.

Figure 13: Welded-wire form facing detail (plantable face fill)

9. Special Considerations

- BX Geogrids typically have different design tensile strengths in the along-the-roll and the across-the-roll directions. Therefore, it is important to install Tensar BX Geogrids in the orientation indicated on the construction drawings.
- If the BX Geogrid strips are placed perpendicular to the slope face, it is not necessary to overlap adjacent strips (Figure 15). However, if the geogrid strips are placed parallel to the slope face, adjacent strips should be overlapped (Figure 16) or alternatively bodkined as indicated on the construction drawings.
- When using LH800 Geogrids in Sierra Slope installations, it is important to note that LH800 Geogrids have design strengths across-the-roll. Therefore, it is important to install them parallel to the slope face.

The Engineered Advantage™

Tensar understands the need for sound engineering as well as proper construction techniques to assure the success of any project. To support this belief, we have a full, in-house professional engineering staff to support your design needs, and a construction operations group to provide on-site installation assistance when necessary. This additional hands-on expertise assures that your project is handled professionally and you will get the results you intend.

For more information on the Sierra System, please call 800-TENSAR-1, visit www.tensar-international.com or e-mail info@tensarcorp.com. We are happy to supply you with additional Sierra Slope product information, complete design guidelines, system specifications, design details, preliminary cost estimates, summaries of completed projects and much more.

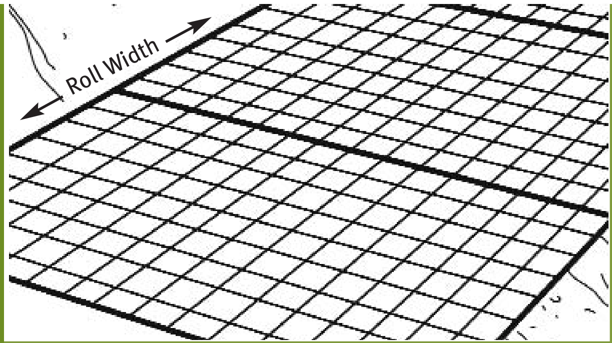


Figure 15: Tensar BX Geogrids placed perpendicular to the slope face.

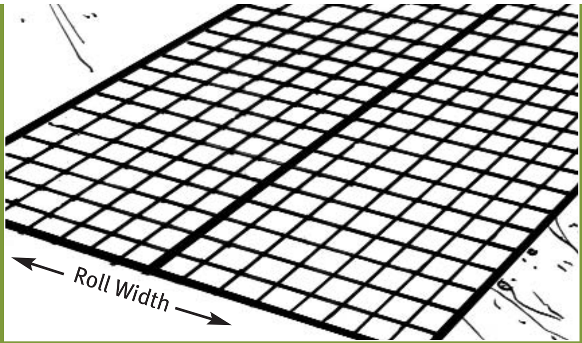


Figure 16: Tensar BX and LH800 Geogrids are placed parallel to the slope face.

Tensar
INTERNATIONAL

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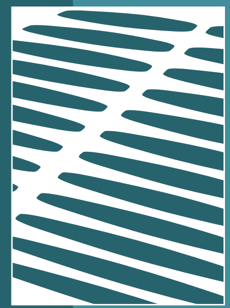
SIERRA_IG_7.06

SIERRA®
SLOPE RETENTION SYSTEM

SYSTEM OVERVIEW

Tensar®
INTERNATIONAL

The Sierra® Slope Retention System provides an economic and aesthetic alternative to conventional retaining walls.



Tensar® Geogrids

The Sierra System owes its strength and durability to Uniaxial (UX) Geogrids, the patented reinforcement geogrids by Tensar International Corporation. Each mechanical component has been designed to work together for optimum efficiency in a variety of challenging site and loading conditions. For more information, visit www.tensar-international.com.

A Complete and Proven System

The Sierra® Slope Retention System, a premier reinforced soil slope (RSS) retention system, was introduced by Tensar International Corporation in 1982.

The Sierra Slope Retention System is a complete and fully integrated mechanically stabilized earth (MSE) system. Each mechanical component has been designed to work together for optimum efficiency in a variety of challenging site and loading conditions.

The cost effectiveness of the Sierra System, coupled with a natural aesthetic appeal, provides an RSS retention system that is routinely specified by government agencies, developers, engineers and architects for a variety of applications:

- Commercial, industrial and retail
- Single- and multi-family residential housing
- Transportation infrastructure
- Recreation facilities
- Municipal water and storm water management

A “Green” Alternative

Tensar International Corporation strives to be an outstanding corporate citizen and is dedicated to creating earth stabilization solutions that are structurally sound and environmentally responsible. The Sierra Slope Retention System can blend naturally with the surrounding environment, use a smaller footprint while maximizing land for development and can be vegetated with native plants to reduce or eliminate landscape irrigation. Because of this green alternative to traditional retaining wall solutions, the Sierra Slope Retention System may be considered a candidate for Leadership in Energy and Environmental Design (LEED®) certification, when used in accordance with LEED guidelines established by the United States Green Building Council.

Note: Tensar International Corporation makes no claim that by using the Sierra System the U.S. Green Building Council (USGBC) will approve a project for LEED certification. It is up to the end user to ensure the use of the Sierra System conforms to the guidelines established by the USGBC. Suitability of the Sierra System for a project should be assessed by a registered professional engineer and installation contractor.

Sierra® System Components

COMPONENT	FUNCTION
Tensar Uniaxial (UX) Geogrids	Primary reinforcement that internally reinforces the soil structure and fill materials.
Tensar Biaxial (BX) Geogrids	Secondary reinforcement that provides surficial stability of the slope structure.
Site-Specific Facing System	Provides aesthetic value by offering multiple facing options, including bioengineering.
Engineering Services	Engineering, design drawings and initial site assistance available upon written contract. Other elements (including leveling pad, backfill and drainage) are supplied by others.

Westlake Village Shopping Center – Austin, TX

These photographs depict three different stages during the construction of a Sierra Slope.

Why Choose the Sierra Slope Retention System?

Economical

- Create usable land in previously undeveloped areas
- Save up to 60% versus conventional concrete retaining walls
- May allow for lower quality fills so on-site soils are usually acceptable
- Installs quickly and without specialized equipment

Flexible

- Create slopes from 26° to 70° to fit site development conditions
- Use a smaller footprint while maximizing land for development
- Create curved slopes and varying face angles for a more natural look
- Specify a variety of facing options – from erosion blankets to professionally landscaped vegetation

Attractive

- Blends naturally with the surrounding environment
- Not subject to facial distortions and cracking like concrete walls
- Resists the effects of differential settlement and seismic activity

Proven

- Over 40 million square feet of the Sierra Slope System have been installed
- Stands up to the most critical loading situations: railways, bridge abutments and building foundations
- Sierra Slopes have adapted to extreme conditions and withstood multiple seismic events exceeding 0.4g
- Constructed with high performance Tensar® Geogrids

Ridgegate – La Jolla, CA

Natural slopes were too unstable to support new homes until the Sierra System was used. With Sierra Slopes, the developer was able to create 21 additional lots and save $500,000 over the alternative of soil cement.

The Spanish Hills Golf and Country Club – Camarillo, CA

This site was considered economically undevelopable until the Sierra System was proposed. The value and appearance of the land has been enhanced dramatically with Sierra Slopes.

Optimal Solutions Based on Site Constraints

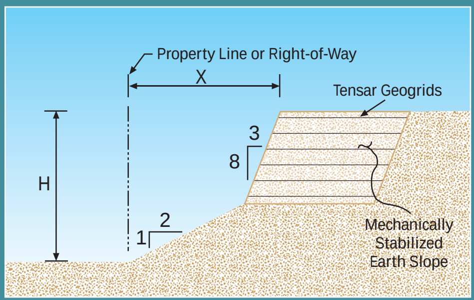
Site Specific Solutions

The Tensar® Sierra® Slope System was developed to provide a designer with countless layout and slope angle options. The flexibility of the Sierra Slope System makes it a common choice when solving grade separation challenges.

Designers and owners are continually faced with different property and site constraints that create grade separation challenges. Some projects may require a very steep grade change in which a green, vegetative solution is the right solution, such as this residence in Pittsburgh, PA. Other projects may utilize complementary grade separation solutions, such as the Mesa® Retaining Wall Systems, combined with the Sierra Slope System to create a dramatic and cost-effective solution. The examples on this and the following page demonstrate some of the system's design flexibility.

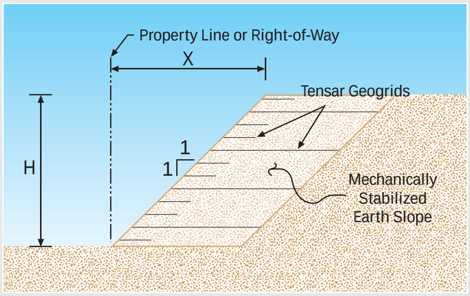
Private Residence – Pittsburgh, PA

This project combines steep and flatter Sierra Slopes to accommodate limited property constraints.

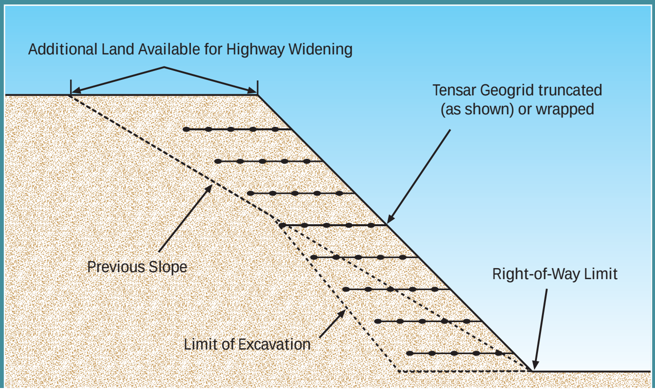


Marriott Riverchase – Hoover, AL

The Sierra System easily adapts to a wide range of slope and slope/wall combinations, but the 1H:1V, as used for the Marriott in Hoover, AL, remains the most commonly specified Sierra Slope.



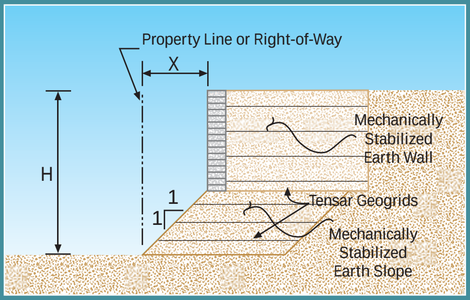
This illustration shows how Departments of Transportation use the Sierra System to stay within restricted rights-of-way while maximizing land use.



Flexible Solutions for Grade Separation Challenges

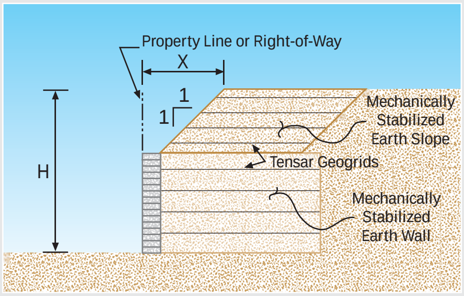
Pearl Street – Braintree, MA

Combine Sierra Slopes and Mesa® Retaining Walls on projects where vertical retention along with reduced material and labor costs are essential.



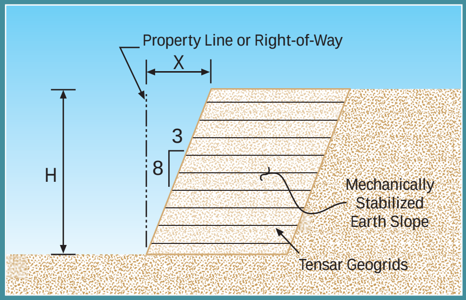
Vinings at Geist Apartment Complex – Lawrence, IN

A Sierra Slope softens the look of the Mesa® Retaining Wall Systems and adds natural green space to maximize limited land when faced with boundary constraints.



Bridge Street – Irwin, PA

Use individual Sierra Slopes to replace retaining walls as shown in this Pennsylvania DOT project.



Sierra Slopes provide a combination of performance, economy and beauty which is why they are often preferred over other types of earth retention systems.

Cost-effective Alternative to Retaining Walls

Options for Steep Slopes Greater Than 45Á

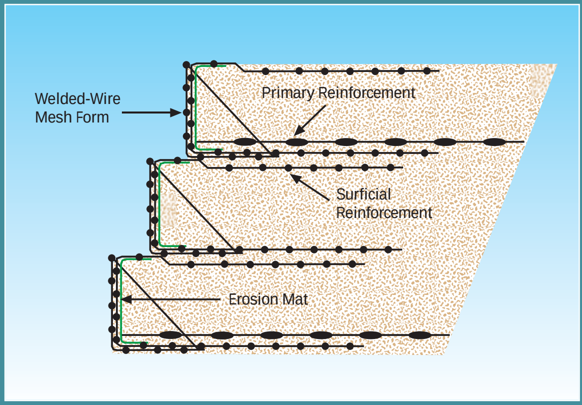
Slopes over 45˚ typically incorporate stair-stepped, welded wire mesh forms (WWF) that simplify installation. A black steel welded wire form is used to develop a wrap face system that is left in place to aid in compaction and face alignment in steep slope applications. A synthetic wrap system of Tensar® Biaxial Geogrid and North American Green® Permanent Erosion Control Blanket provides the long term stability and erosion control at the slope face.

To address walls greater than 70˚, Tensar International Corporation now offers the SierraScape® Retaining Wall System. This welded wire basket system connects Tensar® Geogrid to the SierraScape System Basket using a positive, mechanical connection.

This connection reduces the potential for surficial stability problems. For further information on this system, please see the SierraScape System Overview Brochure. To obtain a copy call 800-TENSAR-1, visit www.tensar-international.com or ask your local representative.

Banks County Landfill – Banks County, GA

The Sierra System was used to create 1H:1V inboard slopes and 1H:6V outboard slopes to increase disposal capacity at this landfill without expanding the footprint.



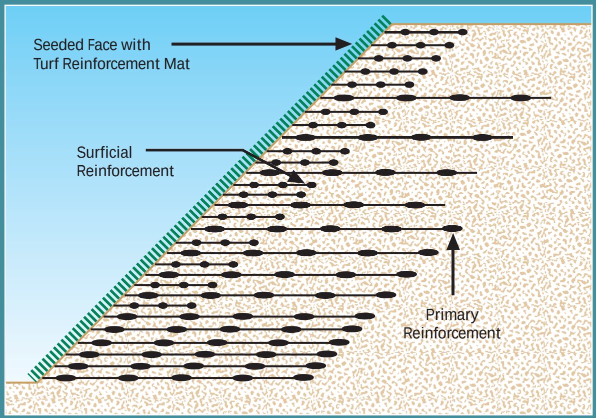
The structural integrity of the Sierra Slope System has been proven in a variety of challenging site and load conditions, including the support of buildings and earthquake loadings.

Natural Facing Options

Poland Spring Plant Expansion – Poland Spring, ME

Hydroseeding

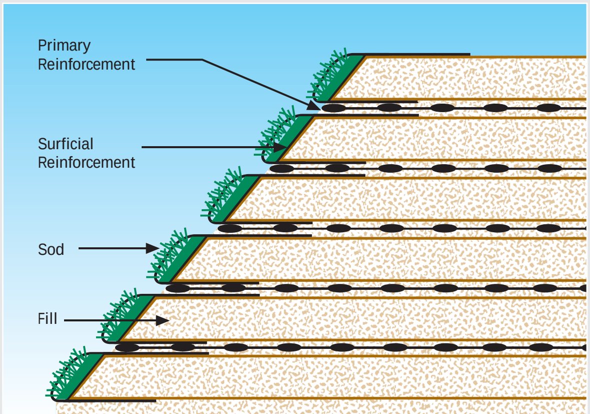
Flower or grass seed installs quickly and is a low-cost alternative for many projects, including overpasses and roadways.



Seabreeze Bridge – Daytona Beach, FL

Sod

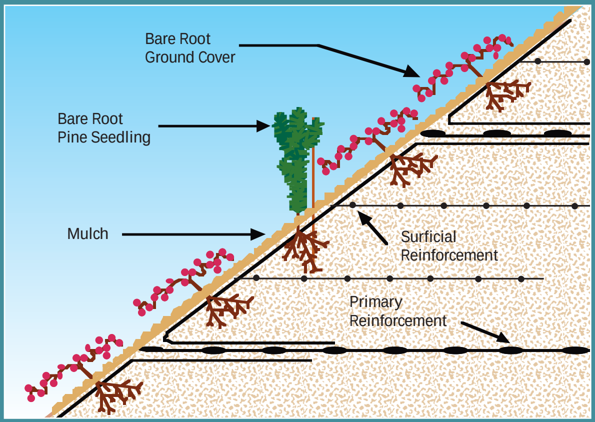
Instantly presents a finished look, as well as an affordable option for landscaped site development.



PR 147 – Naranjito, Puerto Rico

Native Vegetation/Bioengineering

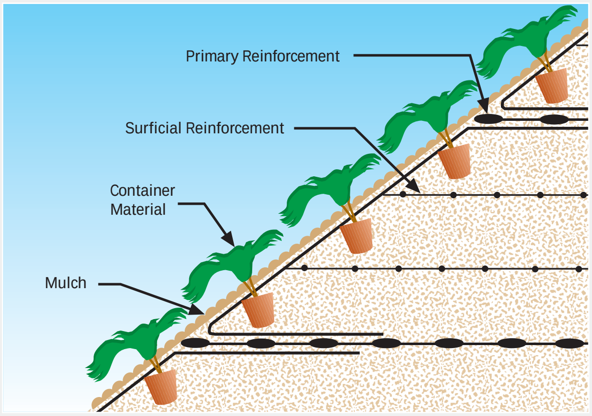
Protects and restores areas disturbed by construction or natural disaster with native plantings.

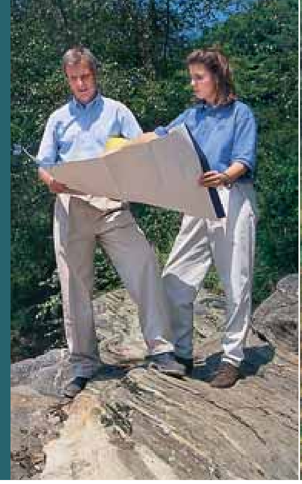


Colegio Alemán – Santiago, Chile

Landscape Engineering

Installs easily into the slope face to immediately enhance the appearance and value of marquee residential or commercial sites.



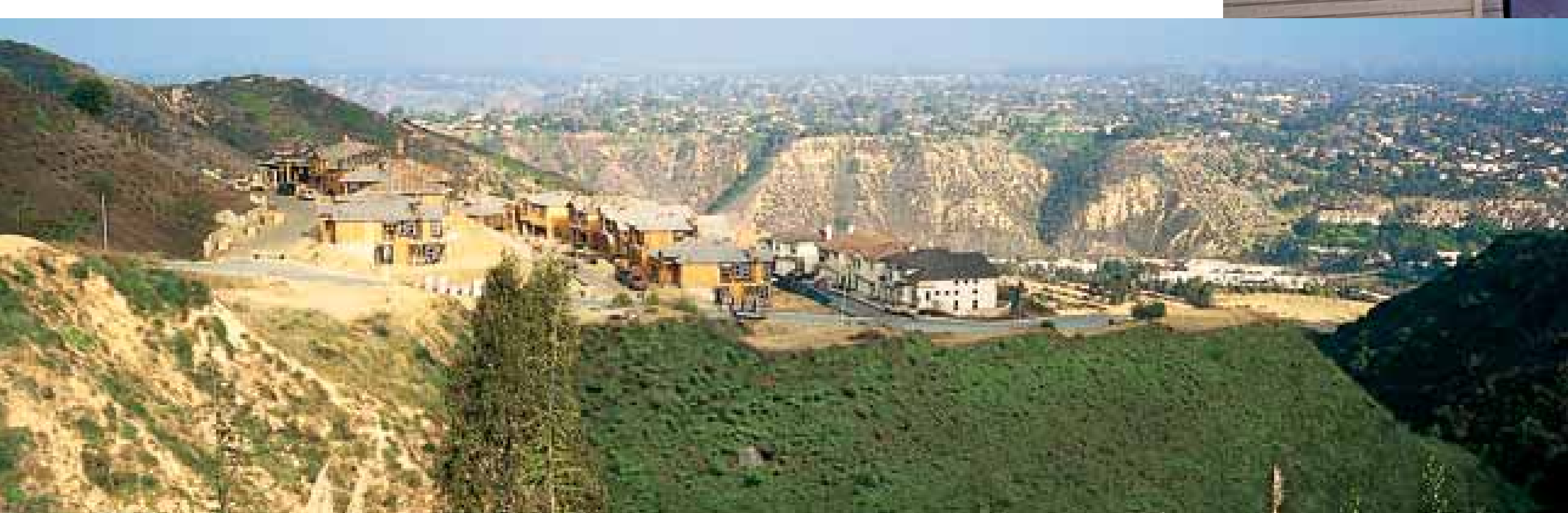


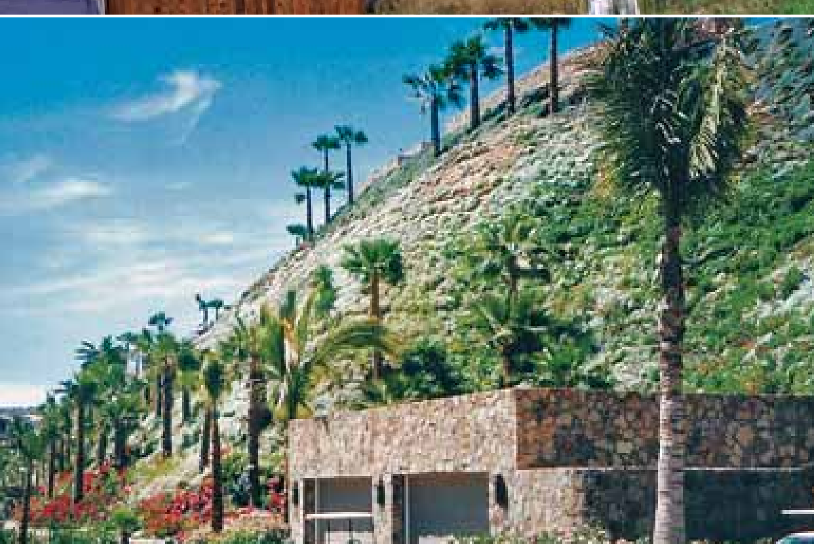

The Engineered Advantage™

The Sierra Slope Retention System has increasingly become the system of choice for residential, commercial and transportation applications. By combining beauty with efficiency and performance, the Sierra Slope System is built to stand the test of time.

Our distribution team throughout the United States, Canada, Europe and Latin America is dedicated to providing you with the highest quality products, service and support. With a technically trained field sales staff and an in-house engineering department, Tensar International Corporation succeeds in keeping its systems at the forefront of today's design technology and market trends.

For more information on the Sierra Slope Retention System, please call 800-TENSAR-1, visit www.tensar-international.com or email info@tensarcorp.com. We are happy to supply you with additional product information and proven case studies. Upon request and under written contract, we can also provide sealed construction drawings and site design and assistance.



Tensar
INTERNATIONAL

A tensar® Company

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Distributed by:

SECTION 02260

MECHANICALLY STABILIZED EARTHEN SLOPES

Display hidden notes to specifier by using “Tools”/”Options”/“View”/”Hidden Text”.

PART 1 GENERAL

1.1 SECTION INCLUDES

A. ** NOTE TO SPECIFIER ** Delete items below not required for project.
B. Mechanically stabilized earth (MSE) steep slope system with high-density polypropylene reinforcing geogrids.

C. Face Fill and Backfill.

D. Geotextile, Turf Reinforcement Mat and Drainage Composite.

1.2 RELATED SECTIONS

A. Document 00300 - Information Available to Bidders: Geotechnical Report; Bore hole locations and findings of subsurface materials.

B. Section 01400 Testing and Inspection Services.

C. Section 02200 - Site Preparation.

D. Section 02300 - Earthwork; Excavation and preparation.

E. Section 02310 - Grading.

F. Section 02315 - Excavation.

G. Section 02316 - Fill and Backfill.

H. Section 02834 - Mechanically Stabilized Earthen Retaining Walls.

I. Section 02920 - Lawns and Grasses; Ground cover at finished grade.

1.3 REFERENCES

A. AASHTO M288 - Standard Specification for Geotextiles.

B. AASHTO Standard Specification for Highway Bridges.

C. ASTM D 698 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.

D. ASTM D 1556 - Standard Test Method for Density of Soil in Place by the Sand-Cone Method.

E. ASTM D 2167 - Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.

F. ASTM D 2922 - Standard Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

G. ASTM D 3017 - Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth).

H. ASTM D 4355 - Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).

I. ASTM D 4716 - Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.

J. ASTM D 6637 - Determining Tensile Properties of Geogrids by the Single or Multi-Rib Test Method; 2001.

K. ASTM F 904 - Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials; 1991.

L. GRI-GG2 - Standard Test Method for Geogrid Junction Strength.
M. FHWA NHI-00-043 – Mechanically Stabilized Earth Walls and Reinforced Soil Slope Design and Construction Guidelines (Demonstration Project 82), March 2001.
N. Tensar Earth Technologies, Inc. “SIERRA Slope Retention System Design Guidelines”.
O. FHWA Federal Highway Administration - Design Guidelines.

1.4 SUBMITTALS

A. Submit under provisions of Section 01300.

B. Product Data: Manufacturer's data sheets on each product to be used, including:
  1. Preparation instructions and recommendations.
  2. Storage and handling requirements and recommendations.
  3. Installation methods.

C. Shop Drawings: Engineering drawings, elevations, and large-scale details of elevations, typical sections, details, and connections.
  1. Include design calculations sealed by a Registered Professional Engineer licensed in the State where the project is located.
  2. Manufacturer's certifications that the ultimate tensile strength and junction strength of the geogrid are equal to or greater than those specified.

D. Samples: Two samples of each wall system component including:
  1. Geogrids: 4 inch by 18 inch (100 mm by 450 mm) piece.
  2. Geotextile: 4 inches by 8 inches (100 mm by 200 mm) piece
  3. Turf Reinforcement Mat: 4 inches (100 mm) by 8 inches (200 mm) piece.
  4. Drainage Composite: 4 inches by 8 inches (100 mm by 200 mm) piece.

E. Manufacturer's Certificate: Certify Products meet or exceed specified requirements.

1.5 QUALITY ASSURANCE

A. Design Requirements: Design retaining wall system in accordance with the local codes and regulations and the design guidelines of FHWA or Tensar Earth Technologies, Inc. Design shall be by a professional engineer registered in the state where the project is located and who is employed by a firm that has designed at least five projects of similar construction and scope.

B. Manufacturer Qualifications: MSE wall system components manufactured by Tensar Earth Technologies, Inc. and companies approved and authorized by Tensar Earth Technologies, Inc.

C. Installer Qualifications: Firm with documented experience of at least five projects of similar construction and scope. Include brief description of each project and name and phone number of owner's representative knowledgeable in each listed project.

D. Pre-Construction Meeting: Prior to construction of retaining walls, conduct a meeting at the site with the retaining wall materials supplier, the retaining wall installer, and the Contractor to review the retaining wall requirements. Notify the Owner and the Engineer at least 3 days in advance of the time of the meeting.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Store products in manufacturer's unopened packaging until ready for installation.

B. Prevent excessive mud, fluid concrete, epoxy, or other deleterious materials from coming in contact with and affixing to retaining wall materials.

C. Polymeric Materials: Store at temperatures above minus 20 degrees F (minus 29 degrees C); rolled materials may be laid flat or stood on end.

1.7 PROJECT CONDITIONS

A. Do not place backfill when subgrade is wet or frozen.

B. Do not place backfill during wet or freezing weather that prevents conformance with specified compaction requirements.

PART 2 PRODUCTS

2.1 MANUFACTURERS

C. A. Acceptable Manufacturer: Tensar Structural Geogrids: The Tensar Corporation, Inc. 1210 Citizens Parkway, Morrow, GA 30309
1.

D. Substitutions: Not permitted.

E. Requests for substitutions will be considered in accordance with provisions of Section 01600.

2.2 MATERIALS

F. Structural Geogrid: Tensar UX1100HS: Polymeric grid formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth; functions primarily as reinforcement.
1. Ultimate Tensile Strength: 3970 pounds per linear foot (58 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 3,690 pounds per linear foot (54 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

G. Structural Geogrid: Tensar UX1400HS: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength: 4800 pounds per linear foot (70 kN/M), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 4520 pounds per linear foot (66 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

H. Structural Geogrid: Tensar UX1500HS: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength: 7810 pounds per linear foot (114 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 7200 pounds per linear foot (105 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

I. Structural Geogrid: Tensar UX1600HS: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength: 9870 pounds per linear foot (144 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 9250 pounds per linear foot (135 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

J. Structural Geogrid: Tensar UX1700HS: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength: 11990 pounds per linear foot (175 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 10970 pounds per linear foot (160 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.
3.

K. Structural Geogrid: Tensar UX1800HS: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength: 14390 pounds per linear foot (210 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.
2. Junction Strength: 12340 pounds per linear foot (180 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.
3.

L. Structural Geogrid: Tensar BX1200: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength (cross machine direction): 1970 pounds per linear foot (28.8 kN/m), minimum average roll value, when tested in accordance with ASTM D6637.
2. Junction Strength: 1830 pounds per linear foot (26.7 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

M. Structural Geogrid: Tensar BX1100: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.
1. Ultimate Tensile Strength (cross machine direction): 1300 pounds per linear foot (19 kN/m), minimum average roll value, when tested in accordance with ASTM D 6637.

2. Junction Strength: 1200 pounds per linear foot (17.5 kN/m), minimum average roll value, when tested in accordance with GRI-GG2.

N. Slope Face Wrapping Geogrid: Tensar BX1120: Polymeric grid formed by regular network of integrally connected tensile elements with apertures of sufficient size to retain a 1-inch to 2-inch (25-mm to 50-mm) Stone Face Fill.
1. Aperture Size: 1 inch by 1.3 inches (25 mm by 33 mm).
2. Carbon Black Content: 2.0 percent.

O. Stone Fill: Free draining, uniformly graded stone placed immediately behind the face of the wire mesh facing unit.
1. 100 percent passing a 4-inch (100 mm) sieve.
2. 0 to 10 percent passing a 2-inch (50 mm) sieve.
3. 100 percent passing a 2-inch (50 mm) sieve.
4. 0 to 15 percent passing a 1-inch (25 mm) sieve.

P. Plantable Fill: Fine grained organic soil placed on the slope for the purpose of supporting vegetation.
1. 100 percent passing a No. 10 sieve (4.75 mm).
2. 0 to 75 percent passing a No. 200 sieve (0.075 mm).
3. LL < 50.
4. PI < 20.

Q. Reinforced Backfill: Granular fill with a pH range of 2 to 12, when tested in accordance with AASHTO T 289, and graded as follows:
1. 100 to 75 percent passing a 2-inch (50 mm) sieve.
2. 100 to 75 percent passing a 3/4-inch (19 mm) sieve.
3. 100 to 20 percent passing a No. 4 sieve (4.75 mm).
4. 0 to 60 percent passing a No. 40 sieve (0.425 mm).
5. 0 to 35 percent passing a No. 200 sieve (0.075 mm).

R. Geotextile: Non-woven geotextile, AASHTO M288, Class 3.

S. Turf Reinforcement Mat: North American Green C350 permanent turf reinforcement mat. Mat shall consist of evenly distributed 100 percent coconut fiber matrix weighing 0.50 lbs per SY (0.27 kg/sq m) encapsulated in a 3-D matting structure consisting of two, top and bottom, heavyweight UV stabilized polypropylene nets, with a nominal weight of 8 lbs/1000 SF (0.04 kg/sq m) and a corrugated high strength center net with an nominal weight of 24 lbs/1000 SF (0.12 kg/sq m). The three nets shall be stitched together on 1.50 inch (38 mm) centers with UV stabilized polypropylene thread to form a permanent three-dimensional turf reinforcement mat with a minimum thickness of 0.5 inches (13 mm).

T. Drainage Composite: Non-woven geotextile, AASHTO M288, Class 3, bonded to both sides of a polyethylene net structure.
1. Minimum Allowable Transmissivity: Not less than 1.5 gallons per minute per foot of width (3 x 10^{-4} square meters per second) when tested in accordance with ASTM D4716 at a confirming pressure of 14.5 pounds per square inch (100 kPa).
2. Minimum Allowable Peel Strength of Geotextile from Polyethylene Net: Not less than 1 pound per inch of width (175 Newtons per meter of width) when tested in accordance with ASTM F 904.

U. Wire Mesh Facing Forms: Steel welded wire mesh facing form, bent 90 degrees at long center line to form “L” shaped unit; vertical section as face to retain fill, and horizontal leg extending into fill; diagonal steel struts supporting top edge of vertical leg.
1. Wire Mesh Facing Unit: Black in accordance with ASTM A 82 and ASTM A 185.
2. Wire Strut Type: Black in accordance with ASTM A 82.
3. Wire Mesh Spacing: 4.0 inches by 4.0 inches (100 mm by 100 mm) (vertical x horizontal wires) unless otherwise indicated on the Drawings.
4. Wire Mesh Minimum Diameters: 0.225 inch (5.72 mm), vertical wires and 0.225 inches (5.72 mm) horizontal wire (before galvanizing).
5. Wire Strut Minimum Diameter: 0.243 inch (6.17 mm).
6. Tie wire or cable ties to connect vertical wires of adjacent facing units.

PART 3 EXECUTION

3.1 PREPARATION

V. Do not begin reinforced slope construction until excavation to foundation elevation has been completed and the foundation for the reinforced fill has been properly prepared.

W. If subgrade preparation is the responsibility of others, notify Architect of unsatisfactory preparation. Do not begin work until unsatisfactory conditions have been rectified.

X. Excavation:
1. Excavate subgrade vertically to plan elevation and horizontally to designed geogrid lengths.
2. Geotechnical Engineer will inspect foundation area to ensure proper bearing strength.
3. Remove soils not meeting required strength and replace with Geotechnical Engineer-approved materials.

Y. Compaction: Compact foundation materials to a minimum of 95 percent Standard Proctor Dry Density in accordance with ASTM D 698.

1.8 CONSTRUCTION

A. Construct Sierra slope system in accordance with approved shop drawings and manufacturer's instructions.

NOTE TO SPECIFIER Facing Form Installation:
1. Place the first course of wire mesh facing forms with the horizontal legs resting on the foundation material.
2. Verify that the first row of facing forms is level from end to end and from front-to-back.
3. Overlap or butt the adjacent facing units. Tie together vertical wires of adjacent facing units as required to maintain alignment and prevent escape of backfill material.
4. Use a string line or equivalent to align straight sections.
5. Place subsequent courses of facing forms on previous courses, at a setback, if any, as shown on shop drawings.
6. Align subsequent courses of facing forms using a string line or other suitable method that is independent of the final position of the underlying course of facing forms.

C. Geogrid placement:

1. Unroll the structural geogrid on the compacted backfill and cut to the length indicated on the shop drawings.
2. Unroll and place uniaxial geogrids perpendicular to the slope face.
3. Cut uniaxial geogrids within 2 inches (50mm) from the thick transverse bar and place that end of the strip at the slope face or to the position near the slope face shown on shop drawings.
4. Unroll and place biaxial geogrid parallel to the slope face unless otherwise shown on shop drawings. Biaxial geogrids may be cut to the required width prior to unrolling.
5. Extend the geogrid and any required turf reinforcement mat beyond the slope face by the amount required for the wrapped face and for anchorage at the top of the wrap.
6. leg of the facing units or wrapping the backfill as indicated on the approved shop drawings. Delete the any of the following four sections that are not required:
7. Place the structural geogrid over the horizontal leg of the facing units. The transverse bar of uniaxial geogrids or the edge of biaxial geogrids shall be positioned immediately behind vertical face of the unit.
8. Place the structural geogrid across the horizontal leg and up the inside of the facing form. Drape the anchorage length of the structural geogrid over the top of the facing form during placement and compaction of the face fill and reinforced backfill.
9. Place the face backing biaxial facing geogrid, geotextile and/or the turf reinforcement mat inside the wire facing form anchored into the fill top and bottom as shown on the shop drawings. After placement of geogrid and any required face wrap, place seven wire support struts on approximately 20-inch (500-mm) centers connecting the upper horizontal wire on the face of facing form to the transverse wire at the rear of the facing form. Place one of the support struts at each end of the facing unit between the outer two vertical wires.Pull the geogrid taut to remove slack.
12. Stake or pin the geogrid near the ends as required to maintain alignment and tension during filling.
13. Place a minimum of 3 inches (75 mm) of fill between any overlapping layers of geogrid where overlapping occurs behind curves and corners of the slope.
14. Rubber tired vehicles may travel on the geogrid at low speeds, less than 5 miles per hour (10 km/hr). Turning of vehicles should be avoided to prevent dislocation or damage to the geogrid and the connected wall facing units.
15. Tracked vehicles shall not be operated directly on the geogrid. A minimum of 8 inches (200 mm) of fill cover over the geogrid is required for operation of tracked construction vehicles in the reinforced zone.

16. **NOTE TO SPECIFIER** Delete paragraphs concerning stone or plantable face file and slope face wrapping where not required.

D. Fill:

1. Place reinforced backfill material and compact to a maximum 9 inches (225 mm) deep lifts. Compact to minimum of 95 percent Standard Proctor Dry Density in accordance with ASTM D 698 to within 3 feet (1 m) of the slope face. Compact the near-face zone using a minimum of three passes.
2. Use only hand operated compaction equipment within 3 feet (1 m) of the slope face.
3. Do not perform soil density testing within 3 feet (1 m) of the slope face.
4. Place geotextile separator and stone or plantable face fill in the zone designated on the shop drawings and compact with hand operated equipment.
5. Place and compact subsequent lifts of fill to the level of the next layer of geogrid reinforcement. Smooth and level (or slope as shown on drawings) to ensure geogrid lays flat.
6. Shape the slope face above the lower level of geogrid reinforcement.
7. Pull any required slope wrapping geogrid and turf reinforcement mat up the slope and over the compacted fill to the distance shown on the shop drawings and stake or anchor as required to maintain alignment and tension.
8. Repeat geogrid and fill placement procedures to top of slope.

9. Place, stake and anchor turf reinforcement mat on slope face as shown on shop drawings.

1.9 FIELD QUALITY CONTROL

A. Testing and Inspection will be provided by the Owners Testing Agency as specified in Section 01400 Testing and Inspection Services. Notify the Architect 72 hours in advance of testing.

B. Testing and Inspection shall be provided by an independent laboratory provided by the Contractor and acceptable to the Architect.

C. Perform laboratory material tests in accordance with ASTM D 698.

D. Perform in place compaction tests in accordance with the following:
   1. Density Tests: ASTM D 1556, ASTM D 2167, or ASTM D 2922 as appropriate for material tested.
   2. Moisture Tests: ASTM D 3017.

E. Frequency of Tests:
   1. Subgrade Soil: A minimum of one test per 1000 SF (100 SM) of surface area.
   2. Reinforced Backfill: Provide one test for every 50 CY (40 CM) of fill placed.

1.10 PROTECTION

A. Protect installed products until completion of project.

B. Touch-up, repair or replace damaged products before Substantial Completion.

END OF SECTION

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Product Specification
Tensar Structural Geogrid

- **UX1000MSE Structural Geogrid**
- **UX1100MSE Structural Geogrid**
- **UX1400MSE Structural Geogrid**
- **UX1500MSE Structural Geogrid**
- **UX1600MSE Structural Geogrid**
- **UX1700MSE Structural Geogrid**

Tensar International Corporation warrants that at the time of delivery the geogrid furnished hereunder shall conform to the specification stated herein. Any other warranty including merchantability and fitness for a particular purpose, are hereby excluded. If the geogrid does not meet the specifications on this page and Tensar is notified prior to installation, Tensar will replace the geogrid at no cost to the customer.

This product specification supersedes all prior specifications for the product described above and is not applicable to any products shipped prior to June 1, 2007

Tensar International Corporation
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Product Specification - Structural Geogrid UX1000MSE

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type: **Integrally Formed Structural Geogrid**
Polymer: **High Density Polyethylene**
Load Transfer Mechanism: **Positive Mechanical Interlock**
Recommended Applications: **MESA System (Segmental Block Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	Units	MD Values[1]
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	23 (1,570)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	46 (3,150)
▪ Junction Strength[3]	kN/m (lb/ft)	43 (2,950)
▪ Flexural Stiffness[4]	mg-cm	400,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	16.8 (1,150)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 76.2 meters (250.0 feet) in length. A typical truckload quantity is 432 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

This product specification supersedes all prior specifications for the product described above and is not applicable to any products shipped prior to June 1, 2007

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Product Specification - Structural Geogrid UX1100MSE

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Product Type:	**Integrally Formed Structural Geogrid**
Polymer:	**High Density Polyethylene**
Load Transfer Mechanism:	**Positive Mechanical Interlock**
Recommended Applications:	**MESA System (Segmental Block Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	**Units**	**MD Values[1]**
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	27 (1,850)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	58 (3,970)
▪ Junction Strength[3]	kN/m (lb/ft)	54 (3,690)
▪ Flexural Stiffness[4]	mg-cm	500,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	21.2 (1,450)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 76.2 meters (250.0 feet) in length. A typical truckload quantity is 432 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

Tensar International Corporation warrants that at the time of delivery the geogrid furnished hereunder shall conform to the specification stated herein. Any other warranty including merchantability and fitness for a particular purpose, are hereby excluded. If the geogrid does not meet the specifications on this page and Tensar is notified prior to installation, Tensar will replace the geogrid at no cost to the customer.

This product specification supersedes all prior specifications for the product described above and is not applicable to any products shipped prior to June 1, 2007

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Product Specification - Structural Geogrid UX1400MSE

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type:	**Integrally Formed Structural Geogrid**
Polymer:	**High Density Polyethylene**
Load Transfer Mechanism:	**Positive Mechanical Interlock**
Recommended Applications:	**MESA System (Segmental Block Walls), ARES System (Panel Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	**Units**	**MD Values**[1]
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	31 (2,130)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	70 (4,800)
▪ Junction Strength[3]	kN/m (lb/ft)	66 (4,520)
▪ Flexural Stiffness[4]	mg-cm	730,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	25.6 (1,760)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 76.2 meters (250.0 feet) in length. A typical truckload quantity is 432 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

Tensar International Corporation warrants that at the time of delivery the geogrid furnished hereunder shall conform to the specification stated herein. Any other warranty including merchantability and fitness for a particular purpose, are hereby excluded. If the geogrid does not meet the specifications on this page and Tensar is notified prior to installation, Tensar will replace the geogrid at no cost to the customer.

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Product Specification - Structural Geogrid UX1500MSE

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type:	**Integrally Formed Structural Geogrid**
Polymer:	**High Density Polyethylene**
Load Transfer Mechanism:	**Positive Mechanical Interlock**
Recommended Applications:	**MESA System (Segmental Block Walls), ARES System (Panel Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	**Units**	**MD Values**[1]
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	52 (3,560)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	114 (7,810)
▪ Junction Strength[3]	kN/m (lb/ft)	105 (7,200)
▪ Flexural Stiffness[4]	mg-cm	5,100,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	41.8 (2,860)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 61.0 meters (200.0 feet) in length. A typical truckload quantity is 324 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

This product specification supersedes all prior specifications for the product described above and is not applicable to any products shipped prior to June 1, 2007

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Product Specification - Structural Geogrid UX1600MSE

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type: **Integrally Formed Structural Geogrid**
Polymer: **High Density Polyethylene**
Load Transfer Mechanism: **Positive Mechanical Interlock**
Recommended Applications: **MESA System (Segmental Block Walls), ARES System (Panel Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	Units	MD Values[1]
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	58 (3,980)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	144 (9,870)
▪ Junction Strength[3]	kN/m (lb/ft)	135 (9,250)
▪ Flexural Stiffness[4]	mg-cm	6,000,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	52.7 (3,620)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 61.0 meters (200.0 feet) in length. A typical truckload quantity is 216 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

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Product Specification - Structural Geogrid UX1700MSE

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type: **Integrally Formed Structural Geogrid**
Polymer: **High Density Polyethylene**
Load Transfer Mechanism: **Positive Mechanical Interlock**
Recommended Applications: **MESA System (Segmental Block Walls), ARES System (Panel Walls), SierraScape System (Welded Wire Walls)**

Product Properties

Index Properties	Units	MD Values[1]
▪ Tensile Strength @ 5% Strain[2]	kN/m (lb/ft)	75 (5,140)
▪ Ultimate Tensile Strength[2]	kN/m (lb/ft)	175 (11,990)
▪ Junction Strength[3]	kN/m (lb/ft)	160 (10,970)
▪ Flexural Stiffness[4]	mg-cm	9,075,000
Durability		
▪ Resistance to Long Term Degradation[5]	%	100
▪ Resistance to UV Degradation[6]	%	95
Load Capacity		
▪ Maximum Allowable (Design) Strength for 120-year Design Life[7]	kN/m (lb/ft)	64.1 (4,390)
Recommended Allowable Strength Reduction Factors[7]		
▪ Minimum Reduction Factor for Installation Damage (RF_{ID})[8]		1.05
▪ Reduction Factor for Creep for 120-year Design Life (RF_{CR})[9]		2.60
▪ Minimum Reduction Factor for Durability (RF_D)		1.00

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.33 meters (4.36 feet) in width and 61.0 meters (200.0 feet) in length. A typical truckload quantity is 144 rolls.

Notes:

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. True resistance to elongation when initially subjected to a load measured via ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. Load transfer capability determined in accordance with GRI-GG2-05.
4. Resistance to bending force determined in accordance with ASTM D5732-01, using specimen dimensions of 864 millimeters in length by one aperture in width.
5. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
6. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.
7. Reduction factors are used to calculate the geogrid strength available for resisting force in long-term load bearing applications. Allowable Strength (T_{allow}) is determined by reducing the ultimate tensile strength (T_{ult}) by reduction factors for installation damage (RF_{ID}), creep (RF_{CR}) and chemical/biological durability ($RF_D = RF_{CD} \cdot RF_{BD}$) per GRI-GG4-05 [$T_{allow} = T_{ult}/(RF_{ID} \cdot RF_{CR} \cdot RF_D)$]. Recommended minimum reduction factors are based on product-specific testing. Project specifications, standard public agency specifications and/or design code requirements may require higher reduction factors. Design of the structure in which the geogrid is used, including the selection of appropriate reduction factors and design life, is the responsibility of the outside licensed professional engineer providing the sealed drawings for the project.
8. Minimum value is based on Installation Damage Testing in Sand, Silt, and Clay soils. Coarser soils require increased RF_{ID} values.
9. Reduction Factor for Creep determined for 120-year design life and in-soil temperature of 20°C using standard extrapolation techniques to creep rupture data obtained following the test procedure in ASTM D5262-04. Actual design life of the completed structure may differ.

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PRODUCT SPECIFICATIONS

Turf Reinforcement Mats (TRMs)

Product	SC250 Vmax³	C350 Vmax³	P550 Vmax³	P300 Vmax³
Description	Three UV stable-polyprolyene nets, 70% straw 30% coconut fiber	Three UV stable heavyweight polyprolyene nets, 100% coconut fiber matrix	Three UV stable extra heavyweight polyprolyene nets, 100% polyproplene fiber matrix	Two UV stable polypropylene nets, 100% polypropylene fiber matrix
Roll Dimension	2.00 m x 16.91 m (6.50 ft x 55.50 ft)	2.00 m x 16.91 m (6.50 ft x 55.50 ft)	2.00 m x 16.91 m (6.50 ft x 55.50 ft)	2.03 m x 32.92 m (6.67 ft x 108 ft)
Mass/Unit Area	606 g/m² (17.88 oz/yd²)	426 g/m² (12.57 oz/yd²)	728 g/m² (21.5 oz/yd²)	407 g/m² (12 oz/yd²)
Tensile Strength (MD x TD)	7.59 x 11.44 kN/m (520 x 784 lb/ft)	9.60 x 13.28 kN/m (658 x 910 lb/ft)	20.15 x 22.23 kN/m (1381 x 1523 lb/ft)	5.53 x 5.88 kN/m (379 x 403 lb/ft)
Suggested Application	Slopes up to 1:1 & greater Medium to high flow channels	Slopes up to 1:1 & greater High flow drainage channels	Slopes up to 1:1 & greater Extremely high flow channels	Slopes up to 1:1 Extended overland flow areas & high flow channels
Permissible Velocity	Unvegetated 2.9 m/s (9.5 ft/s) Fully vegetated 4.6 m/s (15 ft/s)	Unvegetated 3.2 m/s (10.5 ft/s) Fully vegetated 6.0 m/s (20 ft/s)	Unvegetated 3.8 m/s (12.5 ft/s) Fully vegetated 7.6 m/s (25 ft/s)	Unvegetated 2.7 m/s (9.0 ft/s) Fully vegetated 4.9 m/s (16 ft/s)
Permissible Shear Stress				
Bare Soil				
0.5 Hrs	144 Pa (3.0 lb/ft²)	153Pa (3.2 lb/ft²)	191 Pa (4.0 lb/ft²)	144 Pa (3.0 lb/ft²)
50 Hrs	120 Pa (2.5 lb/ft²)	144 Pa (3.0 lb/ft²)	156 Pa (3.25 lb/ft²)	96 Pa (2.0 lb/ft²)
Vegetated Soil				
0.5 Hrs	478Pa (10.0 lb/ft²)	576 Pa (12.0 lb/ft²)	672 Pa (14.0 lb/ft²)	383 Pa (8.0 lb/ft²)
50 Hrs	383 Pa (8.0 lb/ft²)	478 Pa (10.0 lb/ft²)	576 Pa (12.0 lb/ft²)	383 Pa (8.0 lb/ft²)

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For more information, contact:
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1.800.667.4811 nilex.com

Product Specification - Biaxial Geogrid BX1120

Tensar International Corporation reserves the right to change its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance.

Product Type: Integrally Formed Biaxial Geogrid
Polymer: Polypropylene
Load Transfer Mechanism: Positive Mechanical Interlock
Primary Applications: SierraScape System, ADD[3] System (Exposed Wall Face Wrap)

Product Properties

Index Properties	Units	MD Values[1]	XMD Values[1]
▪ Aperture Dimensions[2]	mm (in)	25 (1.0)	33 (1.3)
▪ Minimum Rib Thickness[2]	mm (in)	0.76 (0.03)	0.76 (0.03)
▪ Tensile Strength @ 2% Strain[3]	kN/m (lb/ft)	4.1 (280)	6.6 (450)
▪ Tensile Strength @ 5% Strain[3]	kN/m (lb/ft)	8.5 (580)	13.4 (920)
▪ Ultimate Tensile Strength[3]	kN/m (lb/ft)	12.4 (850)	19.0 (1,300)
▪ Carbon Black Content	%	2.0	
Structural Integrity			
▪ Junction Efficiency[4]	%	93	
▪ Flexural Stiffness[5]	mg-cm	250,000	
▪ Aperture Stability[6]	m-N/deg	0.32	
Durability			
▪ Resistance to Installation Damage[7]	%SC / %SW / %GP	95 / 93 / 90	
▪ Resistance to Long Term Degradation[8]	%	100	
▪ Resistance to UV Degradation[9]	%	100	

Dimensions and Delivery

The biaxial geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 3.0 meters (9.8 feet) or 4.0 meters (13.1 feet) in width and 50.0 meters (164 feet) in length. A typical truckload quantity is 260 to 350 rolls

Notes

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02. Brief descriptions of test procedures are given in the following notes.
2. Nominal dimensions.
3. True resistance to elongation when initially subjected to a load determined in accordance with ASTM D6637-01 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
4. Load transfer capability determined in accordance with GRI-GG2-05 and expressed as a percentage of ultimate tensile strength.
5. Resistance to bending force determined in accordance with ASTM D5732-01, using specimens of width two ribs wide, with transverse ribs cut flush with exterior edges of longitudinal ribs (as a "ladder"), and of length sufficiently long to enable measurement of the overhang dimension. The overall Flexural Stiffness is calculated as the square root of the product of MD and XMD Flexural Stiffness values.
6. Resistance to in-plane rotational movement measured by applying a 20 kg-cm (2 m-N) moment to the central junction of a 9 inch x 9 inch specimen restrained at its perimeter in accordance with U.S. Army Corps of Engineers Methodology for measurement of Torsional Rigidity.
7. Resistance to loss of load capacity or structural integrity when subjected to mechanical installation stress in clayey sand (SC), well graded sand (SW), and crushed stone classified as poorly graded gravel (GP). The geogrid shall be sampled in accordance with ASTM D5818-06 and load capacity shall be determined in accordance with ASTM D6637-01.
8. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments in accordance with EPA 9090 immersion testing.
9. Resistance to loss of load capacity or structural integrity when subjected to 500 hours of ultraviolet light and aggressive weathering in accordance with ASTM D4355-05.

This product specification supersedes all prior specifications for the produc described above and is not applicable to any products shipped prior to June 1, 2007