

APPENDIX G

Engineering Feasibility Study for the Proposed Quarry Bottom Filter

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August 15, 2008

Nolan Associates
1509 Seabright, Suite 2A
Santa Cruz, CA 95062

Subject: Filter Performance Standards
Bonny Doon Limestone Quarry EIR
Santa Cruz County, California

Dear Mr. Nolan,

At your request, we have performed research to help assess performance standards associated with sand and gravel filters proposed to reduce turbidity in quarry runoff. The quarry runoff is proposed to be infiltrated into the underlying karst groundwater system, recharging springs that feed Liddell Creek. We have additionally researched karst stabilization options, which may be required to reduce the potential for karst hazards associated with dissolution of the marble bedrock as a result of infiltration.

Scope of Services

We have provided the following scope of services:

1. We performed a site reconnaissance to observe the existing quarry configuration, to observe karst features visible from the ground surface, and to collect samples of quarry fines.
2. We performed a full grain size analysis on bulk samples of quarry fines to help determine engineering properties for reuse as engineered fill and filter material.
3. We performed a review of publications to help determine appropriate filter designs, and to determine expected performance standards for the given filter components.
4. We have provided you with schematic plans showing conceptual design features that should be incorporated into a granular filter constructed over karst conditions.
5. We have prepared this letter summarizing the work performed, documenting our research on similar filtration systems and providing conceptual recommendations for the design of granular filters over karst conditions. We have not provided design level recommendations, nor have we provided recommendations regarding construction techniques. This work should be preformed by the project engineer and/or project geologist.

Site Observations and Background Information

During our site visit, we observed general geologic features exposed over the upper 300 foot section of the quarry walls as well as rock structure details that could be observed from the base of the quarry. Infilled sinkholes were observed where cut slopes intersect the ground surface, however, no large open karst features were observed on the quarry walls during our site visit. The marble bedrock that forms the lower 15 foot section of the quarry wall has solution fractures on the order of several inches in width. We could not observe the fracture spacing on the quarry floor as it was obscured by spoils at the time of our site visit. We have been informed that solution fractures are on the order of a few to several inches in width over the quarry floor, similar to those exposed on the lower quarry walls.

Eastward expansion of the quarry, coupled with placement of up to 15 feet of fill at the base of the existing quarry bottom is currently proposed.

All quarry runoff is proposed to be percolated into the base of the existing quarry to recharge the karst aquifer that feeds Liddell Spring. We understand that runoff from the base of the existing quarry contributes to turbidity in Liddell Spring. The proposed quarry expansion project could increase the quantity and turbidity of water proposed to infiltrate into the base of the quarry during active mining. Adequate filtration of the runoff prior to percolation into the karst system is recommended to help reduce spring water turbidity, as karst aquifer systems have little ability to filter groundwater.

Solution cavities that form sinkholes and other karst features form slowly over millennia as water dissolves the marble bedrock. Percolation of surface water into fracture systems in the marble may increase bedrock dissolution rates. Infiltration systems proposed for the quarry base should be designed for the site specific karst conditions, which could include sinkholes, fractures and other features, as determined by the project geologist and geotechnical engineer.

Laboratory Analysis

We performed a particle size distribution analysis (ASMT 422) on a sample of "quarry fines" collected from the on-site stockpile. The results are tabulated below and the grain size distribution graph is appended to this letter:

18%	15%	27%	20%	15%	5%
Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay

The quarry fines are adequate for used as engineered fill, and when properly compacted are likely to have a low to very low permeability.

The "gravel" and "coarse sand" components of the quarry fines may be used for filter media if adequately screened and washed to removed fines. The filter media should not use medium and fine grained carbonate sand because the sand may dissolve over time, reducing grain size and decreasing percolation rates. Consideration should be given to the potential for dissolution of carbonate sand when calculating filter permeability and longevity.

The infiltration system should be designed for the runoff and sediment load associated with the expansion project, as well as that associated with the final reclamation phase of the project. We have provided a feasible design concept for infiltration of runoff into the underlying karst system, while minimizing turbidity.

General Description of Feasible Infiltration Systems

It is proposed to percolate quarry runoff during both the active mining phase of the project, and during the reclamation phase of the project. Active mining is likely to produce an increased sediment load. Active mining will require a robust above ground pre-treatment system that can be regularly maintained. The sediment load, however, should be significantly reduced during the quarry reclamation phase. We are therefore of the opinion that two separate filter designs, one to be employed during active mining and one during the reclamation phase, will be the most efficient approach. Accordingly, the following sections provide a schematic design for two separate filter systems. Both designs are intended to facilitate ease of filter maintenance, which is significant with media filters.

Active Mining Phase Filtration System

A feasible filtration system used to reduce sediment in the expansion area runoff could consist of three components: 1) a pre-treatment settlement basin, 2) a media filter constructed as a horizontal roughing filter, and 3) a vertical sand/gravel percolation trench. All three components should be designed to facilitate regular removal of sediment.

Pre-Treatment Settlement Basin: The settlement basin should be elongate in the flow direction, to increase the residence time of water flowing through the basin. The design should facilitate laminar flow. The basin should be designed to minimize the depth and persistence of standing water during dry periods. A schematic for this pre-treatment pond system is provided on Figures 1 and 2 in plan and cross-sectional views, respectively. A number of possible riser designs are shown in Technical note #84, Watershed Protection Techniques (Schueler and Holland, 2000). Settlement ponds can reduce total suspended solids (TSS) by about 80% (Knox County Tennessee SMM).

Media Filter: The media filter could be designed as a horizontal roughing filter containing three gravel baffles. The range of gravel size would likely decrease from approximately $\frac{3}{4}$ inch in the primary baffle, $\frac{1}{2}$ inch in the mid-section, and $\frac{1}{4}$ inch in the tertiary baffle. The horizontal flow into the rock section should be laminar and evenly distributed over the gravel cross-section. The size of the filter will depend on the anticipated water quantity, TSS and maintenance schedule. Roughing filters can reduce TSS by about 80% to 90%, if adequately maintained (Wegelin 1996, CSQA 2003).

Maintenance will be required to insure that the roughing filter continues to reduce sediment. Maintenance will require periodic gravel washing, or gravel removal and replacement. Gravel washing may require that the gravel is contained in a structure with an engineered flushing system that discharges the backwash into a separate catchment area.

Vertical Sand/Gravel Infiltration Trench: The roughing filter should discharge to a graded bed filter placed in the quarry floor (Figures 1 and 2). This system is similar to the Reclamation Infiltration System, with the omission of the surrounding planting strips and gravel berms. As described below, the base of this infiltration system should be designed as a stabilization layer, with the aggregate clast size selected to span solution fractures, or other karst features, based on field observation. Alternatively, the bottom of the filter can be supported by geotextiles or other means.

The filter should be constructed of aggregate that grades up to a layer of coarse sand that can be periodically raked to remove fines trapped at the surface (or replaced) as needed. Media filters can reduce TSS by 80% to 90%, if adequately maintained (Wegelin 1996, CSQA 2003).

This filtration system for runoff collected from the quarry expansion area may ultimately be integrated with the design of the reclamation infiltration system, which is described below.

Reclamation Infiltration System

The reclamation infiltration system is intended to function as a long term infiltration device following institution of the reclamation plan. The filter is intended to require little maintenance. A feasible infiltration system for the base of the existing quarry could be consist of 1) a stabilization system over the lower section of the trench to mitigate loss of filter material into bedrock fractures, 2) a graded media filter overlying the stabilization system, and 3) gravel filter berms and planting strips to either side of the infiltration trench to reduce sediment in surface runoff and reduce maintenance of the media filter. A possible filter design is indicated schematically on Figures 1 and 2.

1. The base of the infiltration system should be designed to mitigate karst hazards, as identified by the project geologist and geotechnical engineer. Stabilization systems, which could include graded filter media, reinforced concrete slabs, or geotextile fabrics (Proshaka, 2006). Based on the width and distribution of solution fractures observed, it is probable that placing graded filter media at the base of the infiltration trench will be a viable option. The project geologist should inspect the trench bottom prior to placement of filter media to confirm that the size of open fractures or voids does not exceed the design specification.
2. The graded media filter overlying the stabilization system should be constructed with gravel fining upward to the ground surface. Filter fabric should be placed over the sides of the trench excavation so as to minimize the potential for soil loss into the larger aggregate. The upper most aggregate should consist of coarse sand at the ground surface. The permeability of the sand will be significantly reduced when even a minimal silt layer develops at the top of the media filter. The clogged sand layer can be raked to remove fines at the surface or it can be removed and replaced during regular maintenance.

The dimensions of the infiltration trench will depend on the anticipated water quantities, total suspended solids (TSS) and maintenance schedule. Media filters can reduce TSS by 80% to 90%, if adequately maintained (Wegelin 1996, CSQA 2003).

3. Gravel filter berms and planting strips should be constructed surrounding the infiltration trench to remove silt from overland flow on the floor of the reclamation area. The engineered backfill surrounding the infiltration trench (and on the quarry floor) should be very gently sloped (<5%) to reduce the sediment load in overland flow.

Potential Filter System Performance

Filter performance will depend on numerous factors including sizing, design, materials specifications, construction techniques and maintenance. Below is a table of some published data regarding the removal rate of total suspended sediment using various filter techniques.

Potential Filter Performance

Mitigation Type	Design Features	Removal of TSS	Reference
Wet Pond		77%	CRWQCB
Sediment Basin	Perforated riser	94%	Schueler, T. and Holland H., eds., 2000.
Sediment Ponds	Stormwater Ponds	80%	Knox County Tennessee Stormwater Management Manual, Chapter 4.
Sand Filter		80%	Knox County Tennessee Stormwater Management Manual, Chapter 4.
Infiltration Trench		89%	CRWQCB
Surface Sand Filter		83%	CRWQCB
Infiltration Trench		90%	Knox County Tennessee Stormwater Management Manual, Chapter 4.
Media Filter	Sand/Gravel filters	75%-92%	Schueler, T. and Holland H., eds., 2000.
Media Filter	Gravel Roughing Filter	77%-94%	Ochieng, G. M. and Otieno, F. A. O., 2006
Media Filter	Limestone Horizontal Roughing Filter	94% (ave)	Rooklidge, S. J., Ketchum, L.H. and Burns, P.C., 2001
Media Filter	Gravel Roughing Filter (horizontal flow and down flow)	80%-90%	Wegelin, 1996

Filter System Maintenance

All filter systems require regular maintenance to perform adequately. It is anticipated that maintenance will increase with quarry activity and inclement weather conditions. Depending on the final reclamation design, maintenance of the filtration system may be significantly reduced subsequent to active mining activities (reclamation phase).

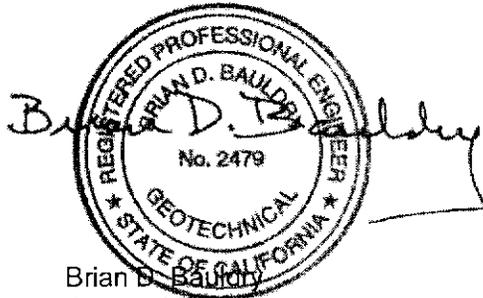
Engineered Fill Surrounding Filter Systems

It is proposed to place about 15 feet of compacted engineered fill over the base of the quarry floor. Based on our observation of the quarry fines, and the soil types surrounding the quarry area, it is likely that resulting engineered fill (if compacted to 90% relative density) will have relatively low permeability. The project geotechnical engineer should determine if this engineered fill has the potential to slope down into bedrock fractures. Geotextile filter fabric could be used to control such stoping, if it is deemed to be a likely.

Limitations

The recommendations presented above are conceptual in nature, and are not intended to be used for design or construction purposes. The actual filter, stabilization and infiltration design should be provided by the project geologists and engineers, and should be based on site specific analysis of existing karst conditions, predicted drainage volumes, and other significant site specific data.

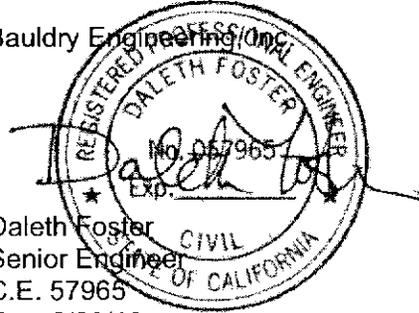
If you have any questions, please contact our office at your convenience.



Brian D. Bauldry
Principal Engineer
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Very truly yours,

Bauldry Engineering, Inc.



Daleth Foster
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Projects/2008/0827/Filter Performance Standards
Copies: 1
Attachment

References:

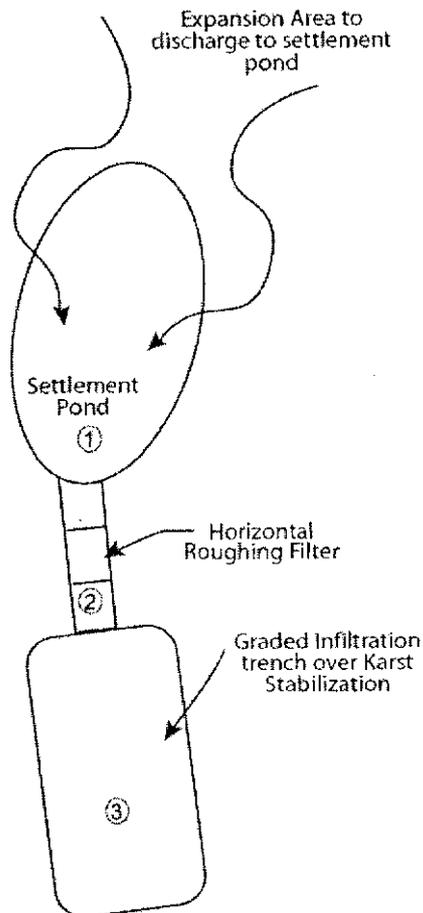
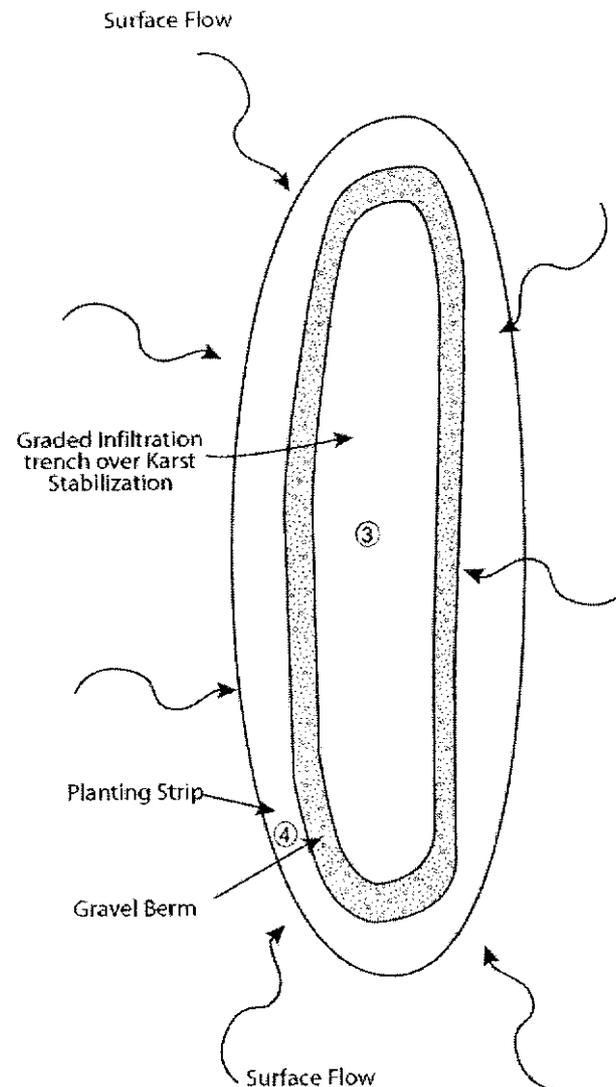
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Wegelin, M. 1996, SANDEC report no 2/96. *Surface Water Treatment by Roughing Filters A Design, Construction and Operation Manual*. Swiss Federal Institute for Environmental Science and Technology (EAWAG), Dept. Water and Sanitation in Developing Countries (SANDEC). ISBN:3-908001-67-6

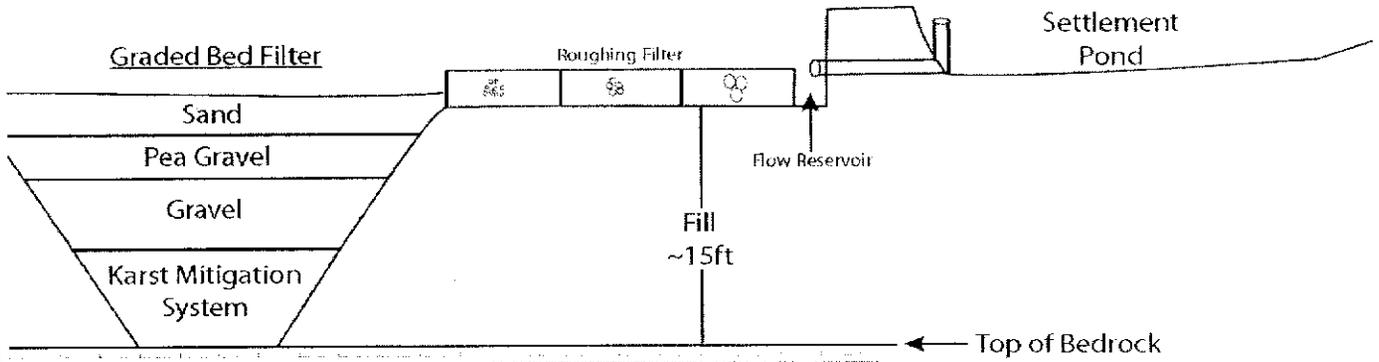
California Regional Water Quality Control Board (CRWQCB). Appendix D.5. Documentation of BMP Ability to Meet the 80% TSS Removal Requirement
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/muni/nrdc/appnd_d5.pdf

Active Mining Phase Filtration SystemReclamation Infiltration System

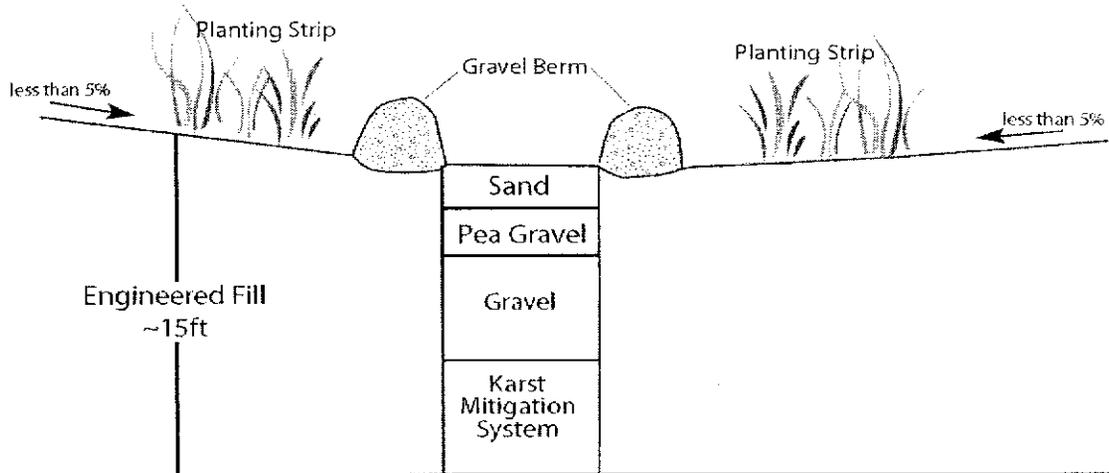
- 1) Settlement Pond, minimum 2 to 1 length to width ratio, constructed for ease of maintenance.
- 2) Graded gravel roughing filter, constructed for ease of maintenance.
- 3) Graded sand and gravel filter overlying Karst Mitigation System. Karst Mitigation System may consist of large aggregate sized to span bedrock voids. Geogrid and/or reinforced concrete slabs may be required pending geologic evaluation of Karst conditions. Maintenance will be required for effective infiltration.
- 4) Surface filtration system: Planting strips and gravel berm surrounding infiltration trench.

NOTE: This is one of many feasible filter configurations.

Active Mining Phase Filtration System

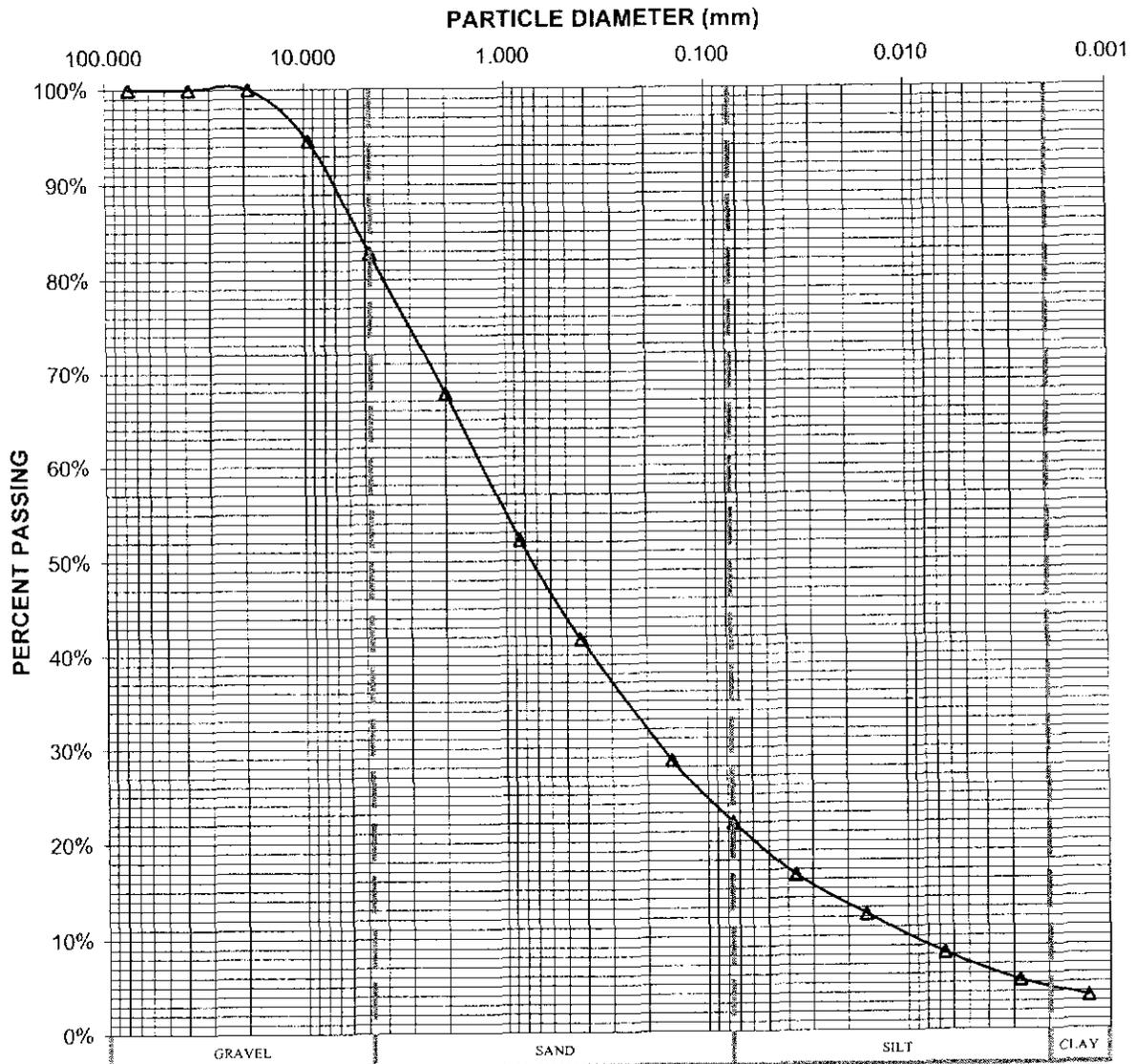


Reclamation Area Infiltration System



PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: Bulk Sample	% PASSING	% PASSING
SOIL TYPE: SM	No. 4	No. 200
	82.8%	22.0%



GRAVEL	SAND	SILT	CLAY
17.2%	60.8%	17.6%	4.4%

$C_u = 140$

$C_c = 2.3$

