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Report

Of

Study on soil conservation while undertaking soil remediation process in mercury contaminated site of Hindustan Unilever Ltd., Kodaikanal

Consultants

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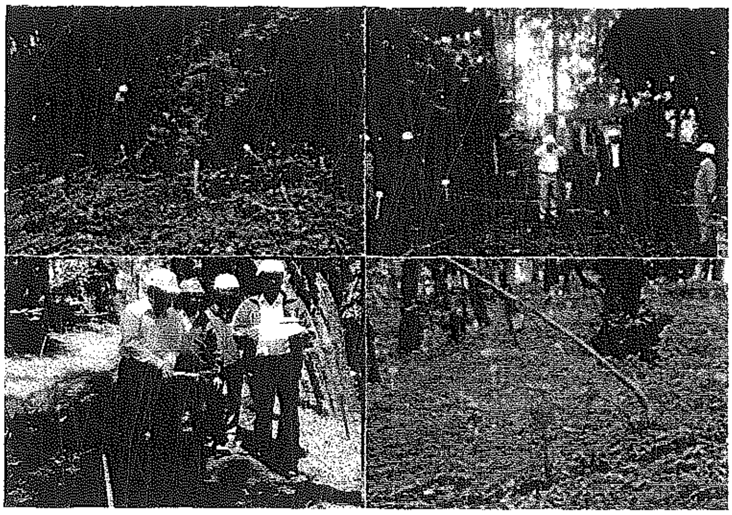

Prepared for

Hindustan Unilever Limited

Kodaikanal

Central Soil & Water Conservation Research & Training Institute: Research Centre

Udhagamandalam - 643 004

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October 2010

GLOSSARY

HUL	: Hindustan Unilever Limited
SCMC	: Supreme Court Monitoring Committee
TNPCB	: Tamil Nadu Pollution Control Board
NEERI	: National Environmental Engineering Research Institute
ERM	Environmental Resources Management
DPR	: Detailed Project Report
ETP	: Effluent Treatment Plant
LCC	: Land Capability Classification
LBTSW	: Loose Boulders Terrace Support Wall
RRCD	: Random Rubble Concrete Masonry Check Dam
GCD	: Gabion Check Dam
LBCD	: Loose Boulders Check Dam

Executive Summary

The mercury in glass thermometer factory was set up by Ponds India Limited at Kodaikanal in 1983 and commenced production in January 1984. It came under the management of Hindustan Lever Ltd. (Presently renamed as Hindustan Unilever Ltd.:- HUL) in September 1998 consequent to the merger of Ponds India Ltd. with it. The manufacturing process for thermometer making include stem cutting of imported glass, followed by end opening, end cutting, bulb forming, mercury filling, top chambering, scale setting, grading, top sealing, screen printing and certification. The manufacturing area had 36 exhaust fans to facilitate air change and maintain the workplace occupational safety standards for air 0.05 mg/Nm^3 of mercury. The expelled air containing mercury vapours from the manufacturing area settled down on the surrounding soils close to the manufacturing area causing contamination of soil and biomass. Detection of glass scrap with residual mercury in a scrap yard at Kodaikanal led the HUL management to close the factory operations in March 2001. Various remedial measures were initiated by HUL immediately thereafter which includes, Retrieval of glass scrap with residual mercury from the scrap yard, environmental site assessment and risk assessment study for mercury, construction of silt traps to prevent discharge of contaminated soil from the factory site, comprehensive medical examination of employees, export of 290 MT of all mercury bearing materials such as glass scrap, finished and semi-finished thermometers, elemental mercury, and ETP sludge to M/s Bethlehem Apparatus, USA for recycling and decontamination of plant and machinery and disposal.

A high power Supreme Court Monitoring Committee (SCMC) on hazardous waste management visited the HUL factory site in September 2004 and directed the Tamil Nadu Pollution Control

Board (TNPCB) to take immediate steps towards assessment and remediation of mercury contaminated areas. Subsequently, SCMC directed TNPCB to involve National Environmental Engineering Research Institute (NEERI), Nagpur during the assessment and remediation of mercury-contaminated areas. NEERI recommended the soil remediation process by excavating the top layer of soil and washing / vacuum retorting of excavated soil followed by backfilling. Necessary protocol for soil remediation process was also developed by NEERI (2008) and details of technical issues to be addressed during remediation process were elaborated. Following the last progress meeting held with TNPCB in Chennai in February, 2010, TNPCB directed HUL to conduct the following studies: (a) peer review of risk assessment report to verify the site specific remediation criteria; (b) report on tree conservation during excavation, treatment and backfilling by the National Botanical Research Institute; and (c) report on soil erosion and suitable control measures by the Central Soil and Water Conservation Research and Training Institute. As directed, Central Soil Water Conservation Research and Training Institute: Research Centre, Udhagamandalam is involved in conducting the soil erosion study while attempting excavation and to propose the suitable conservation measures for preventing soil erosion to the extent possible. As per Terms of Reference (TOR), the study involved the following objectives:

1. Soil conservation study including likely impact on soil while undertaking the remediation process (Excavation and backfilling) as detailed in DPR.
2. Suggest the measures to minimize the impact on soil and soil erosion while undertaking the remediation process as detailed in DPR.
3. Any other suggestions with regards to the soil remediation project including rehabilitation of soil.

4. Presentation of the findings and recommendations of the study to Tamil Nadu Pollution Control Board and Scientific Experts Committee constituted by the Supreme Court Monitoring Committee to monitor soil remediation.

Study area was inspected by study team and the information on soil type and depth, land use pattern were generated. Contour survey at 1m grid was conducted and slope map was prepared. Rainfall and wind velocity data for 10 years period was collected from India Meteorological Department, Chennai and data was analyzed. Nature of vegetation and root distribution system was also examined for stability of erosion. Soil depth study was conducted in 30 locations randomly selected. The information was also generated based on discussion with officials of the Hindustan Unilever Limited and Environmental Resources Management. Mercury distribution and steps involved in soil remediation process was taken from previous reports submitted by NEERI and URS. The major problems expected during the soil excavation and backfilling process were identified and preventive measures to be followed are suggested.

The following problems are identified while excavation of mercury contaminated soil and backfilling the treated soil.

Area 'A': There is the possibility of soil erosion due to steeper slope (33 to 50 per cent) coupled with high intensity of rainfall and high surface runoff. Soil depth is shallow $\leq$ 0.25 m and the rocky patches will be exposed if the soil is excavated up to the depth of 25 cm, resulting in the possibility of movement of mass soil towards valley side. Shallow rooted trees which exist in this area may fall down, even if 30 cm soil is excavated due to heavy wind (6.0 to 9.6 km / hr) and shallow distribution of root system. Backfilling of the soil is not possible in this area due to steep slope and shallow soil depth. As a result of the soil washing process, the cohesion and adhesion properties of soil will be washed away through water. If backfilling of the soil is done after washing, the soil will not stand over the bed rocks since continuous water lubrication will exist between backfilled soil and parent rock (Due to less compactness in backfilled soil, critical slope and accumulation of leaf litter on the top surface).

Area 'B': There is the possibility of soil erosion due to steeper slope (33 to 50 per cent) coupled with higher intensity of rainfall and higher runoff. Shallow rooted trees which are exists in this area may fall down, even if 30 cm soil is excavated due to heavy wind (6.0 to 9.6 km / hr) and shallow distribution of root system. Backfilling of the soil is possible in this area where flat land is available and in sloppy area, only excavation can be done.

Area 'C': Soil erosion will occur, while excavation and refilling process without adopting suitable conservation measures due to slopes ranges from 6 to 20 per cent and high runoff. Removal of top soil containing organic carbon during excavation and backfilling process may bring the land to low productivity.

The following preventive measures are recommended while excavation and backfilling process.

- Keeping in view of high rainfall during the months of May, August, September, October and November, the excavation and backfilling may be attempted during the Months of December to April, June and July. Heavy wind speeds are encountered during the months of January to April, hence proper care needs to be taken while excavating the soil near the trees.
- Keeping in view of steep slope, high rainfall, and shallow soil depth and existing of trees, excavation should be avoided in Area 'A'. Excavation and backfilling can be done in part of the Area 'B' and Area C1 and C2 (As demarked in Map 3) with suitable erosion control measures as recommended in sections 7 and 8.

- In general where the trees are located in dense or close spacing, excavation of soil should be completely avoided. At other places, for specified distances as given in Table 4, the soil should not be disturbed.
- It is suggested to not to disturb the soil where the steep slope area of 'A' Zone (as demarked in Map 3) having above 50 % land slope. Instead, in-situ measures should be taken up to avoid the movement of mercury contaminated soil from this area to neighboring areas. Covering with Geo-Jute blankets and planting grass species will be the suitable option to avoid the soil movement.
- Gabion type of terrace support wall may be constructed on the lower portion of the area 'A' over a length of 150 m which will not allow the mercury contaminated soil to spread over other areas in future. The boulders which are already available in the site can be used for this purpose.
- In part of the area 'A' (near scrap yard), excavation of soil may be restricted to 25 cm depth and backfill the washed soil in Area C2. While excavating in the leveled portion of this area, inward terrace system may be followed with 2:1 slope. Riser part may be maintained with 1:1 slope ratio. Riser part may be covered with Geo-Jute erosion control blanket and grass roots may be planted.
- In parts of the area 'A' (Only leveled portion where there is no trees and area 'B' (Near the tress) where soil can be excavated up to 20 cm depth, immediate backfilling is recommended by filling external soil. Necessary quantity of soil may be excavated from the residential quarters located within the premises and filled in this area followed by immediate grass turfing. The excavated soil in these patches may be treated and backfilled in area C1 and C2.

- Stone bunds at 0.5 m vertical interval may be constructed in slope area where trees are available to avoid soil erosion in Area 'B'. The boulders which are already available in the site may be utilized.
- It is suggested that Gabion type of retaining wall on the lower portion of the area "B" over a length of 150 m which will not allow the contaminated soil to spread to over other areas.
- It is proposed to construct Random Rubble Stone Masonry Check Dam (RRCD) in the lower portion of the gully located in between area A & area B.
- Gabion Check Dam (GCD) on the upper portion of the gully may be constructed to collect the eroded soil which will be washed with runoff after immediate backfilling. This soil can be desilted and it can be spread over the areas in future time.
- In area 'C1", Excavation of soil may be restricted up to 0.35 m depth.
- Soil may be backfilled by forming terraces and terrace support walls may be constructed in each terrace.
- Root slips of the Vegetative barriers viz. Guatemala (*Tripsacum laxum)* and Kikyu *(Pennisetum clandestinum)* should be planted at recommended spacings on terrace after backfilling the treated soil to control erosion in Area C1 and C2.
- In slope area nearby factory building, soil may be excavated at 1:1 slope ratio and turfing of Kikyu grass *(Pennisetum clandestinum)* may be laid out.
- Drainage lines passing through the area C1 and C2 may be treated with three numbers of loose boulders check dam with trapezoidal section.
- In area C2, Excavation of soil should not exceed the depth of 0.6 m in this area. In vertical slope area near factory building, the excavation should be restricted to a depth of 0.30 m.

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Study on soil conservation while undertaking soil remediation process in mercury contaminated site of Hindustan Unilever Ltd., Kodaikanal

1.0 Introduction

The mercury in glass thermometer factory was set up by Ponds India Limited at Kodaikanal in 1983 and commenced production in January 1984. It came under the management of Hindustan Lever Ltd. (Presently renamed as Hindustan Unilever Ltd.:- HUL) in September 1998 consequent to the merger of Ponds India Ltd. with it. The factory was a 100 % export oriented unit and the clinical thermometers were mainly exported to the countries such as USA, Europe, South America and Australia. The factory produced around 9 million thermometers per year; and about 165 million pieces were exported between 1984 and 2001. The manufacturing process for thermometer making include stem cutting of imported glass, followed by end opening, end cutting, bulb forming, mercury filling, top chambering, scale setting, grading, top sealing, screen printing and certification. The manufacturing area had 36 exhaust fans to facilitate air change and maintain the workplace occupational safety standards for air 0.05 mg/Nm^3 of mercury. The expelled air containing mercury vapours from the manufacturing area settled down on the surrounding soils close to the manufacturing area causing contamination soil and biomass. Detection of glass scrap with residual mercury in a scrap yard at Kodaikanal led the HUL management to close the factory operations in March 2001. The following remedial measures were initiated by HUL immediately thereafter:

1. Retrieval of glass scrap with residual mercury from the scrap yard
2. Environmental site assessment and risk assessment study for mercury
3. Construction of silt traps to prevent discharge of contaminated soil from the factory site
4. Comprehensive medical examination of employees
5. Export of 290 MT of all mercury bearing materials such as glass scrap, finished and semi-finished thermometers, elemental mercury, and ETP sludge to M/s Bethlehem Apparatus, USA for recycling, and

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6. Decontamination of plant and machinery and disposal.

A high power Supreme Court Monitoring Committee (SCMC) on hazardous waste management visited the HUL factory site in September 2004 and directed the Tamil Nadu Pollution Control Board (TNPCB) to take immediate steps towards assessment and remediation of mercury contaminated areas. Subsequently, SCMC directed TNPCB to involve National Environmental Engineering Research Institute (NEERI), Nagpur during the assessment and remediation of mercury-contaminated areas. NEERI recommended to soil remediation process by excavating the top layer of soil and washing / vacuum retorting of excavated soil followed by backfilling. Necessary protocol for soil remediation process was also developed by NEERI (2008) and details of technical issues to be addressed during remediation process were elaborated. Following the last progress meeting held with TNPCB in Chennai in February, 2010, TNPCB directed HUL to conduct the following studies:

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1.1 Scopes and Objectives

As directed, Central Soil Water Conservation Research and Training Institute: Research Centre (CSWCRTI RC) Udhagamandalam is involved in conducting the soil erosion study while attempting excavation and propose the suitable conservation measures to prevent soil erosion to the extent possible. As per Terms of Reference (TOR), the study involved the following objectives:

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2.0 Description of the study area

The former HUL factory site is located at an elevation of 2,180 m which forms a divide between two catchment areas, one located to the south and the other to the north. The southern catchment area includes the factory and the Pambar River, while the northern catchment area includes Kodai Lake (Map 1). The Kodai Lake is located approximately 1.0 km north of the site. The nearest surface water body to the site is the Pambar River which flows in a southwest direction to the Kumbakarrai Falls about 7 km to the southeast, thence draining eastward across the Tamil Nadu Plain. A narrow access path, the Levange path, is in the Forest Reserve immediately south of the site boundary. This path lies immediately above the precipitous slopes and is primarily on bedrock with only a thin veneer of soil The general land use to the north and east of the site is largely low density private residential properties along St. Mary's Road.

2.1. Geological conditions of the site

The whole site is underlain by shallow Archaean bedrock, mainly granite gneiss and chaipockite, which is impermeable apart from the limited fracture porosity, related to vertical and sub-horizontal joints and exfoliation joints in the upper most weathering profile. The soil profile is very shallow, and comprises a few centimeters of predominantly sandy material in the upper part of the site grading down into densely vegetated peaty soils in the south and depth is varies from 0.30 m to 1.5 m. Two shallow wells on site which are blasted into the rock have limited supplies of water which decline markedly in the summer season.

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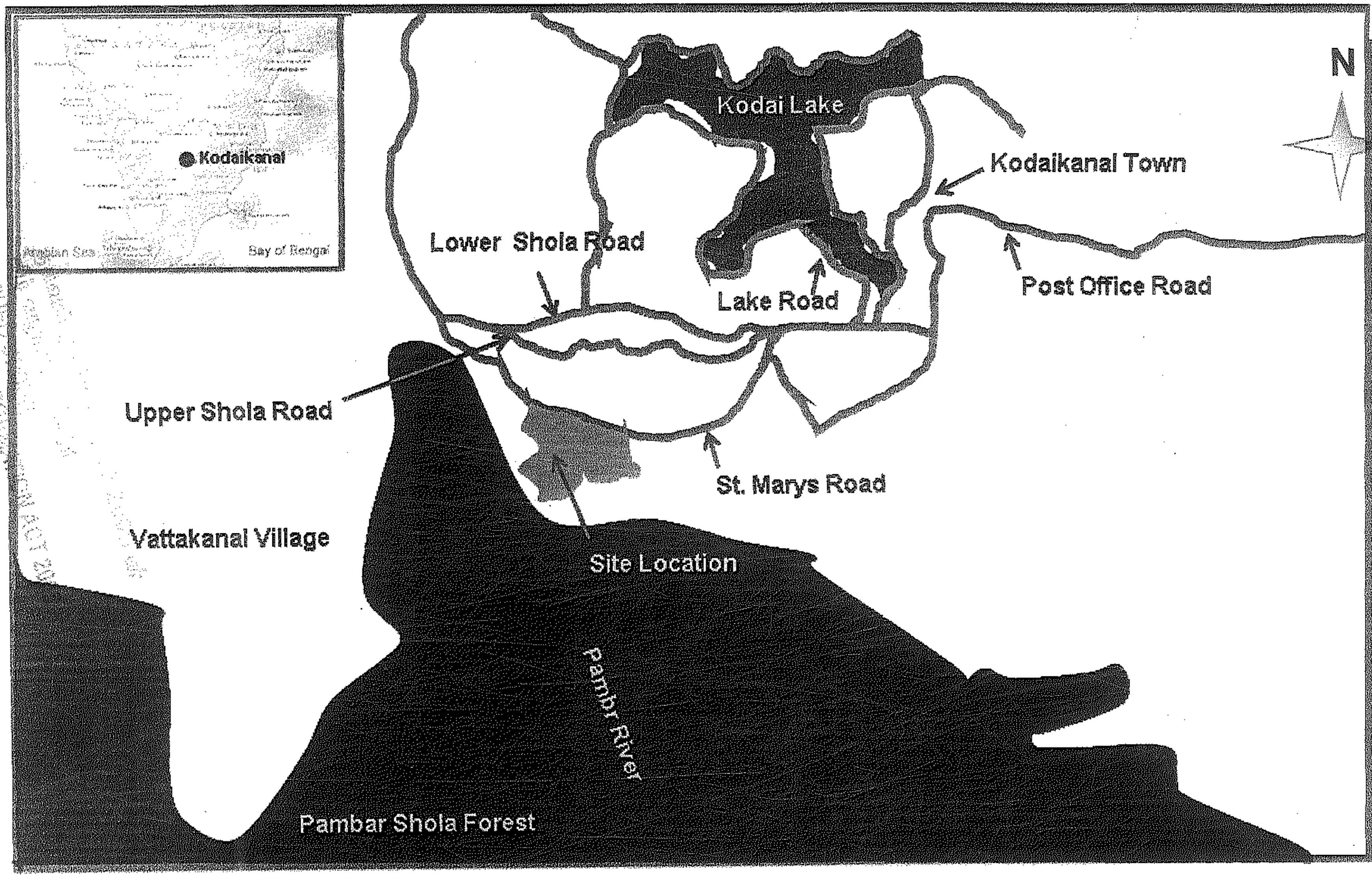

Map 1: Location of Mercury Contaminated site of Hindustan Unilever Limited, Kodaikanal

2.2. Land Use of study area

In area A, 70-80 percent of the area is covered with Eucalyptus plantations, 10 per cent area is covered with shrubs and Shola species and remaining area is full of rocky areas .

In area B, more than 80 percent of the area is covered with Eucalyptus plantations, remaining 20 per cent area is covered with shrubs and grass lands .

In area C1, more than 45 percent of the area is covered with Horticulture plantation like Beri and Plums, 15 per cent area is covered with grass lands and remaining 40 per cent area was covered with buildings

In area C2, more than 90 percent of the area is covered with grass land remaining 10 per cent area is covered with buildings

2.3 Land capability classification

Land capability classification (LCC) is crucial for choosing suitable land use options and appropriate soil and water conservation practices. Field survey was carried out in HUL area to classify the land into different LCC classes. The prevailing LCC in the HUL area are I, II, III, IV and V with (Table 1). The LCC map is shown in Map 2.

Table 1: Area under various LCC classes of HUL factory site at Kodaikanal

LC class	Area (ac)	Area (Per cent)	Mapping Unit
I	1.00	6.00	$\frac{\text{cl-d}_5}{\text{A-e}_1}$
II	-	-	-
III	7.01	42.05	$\frac{\text{cl-d}_4}{\text{C/D-e}_2\text{/e}_3}$
IV	2.75	16.50	$\frac{\text{cl-d}_{2/4}}{\text{E/F-e}_3}$
V	-	-	-
VI	0.89	5.34	$\frac{\text{cl-d}_{2/3}}{\text{G-e}_4}$
VII	5.02	30.11	$\frac{\text{cl-d}_{2/3}}{\text{H-e}_4}$

cl: sandy clay loam, A, C, D,E,F & G: slope group, e: erosion status

2.3.1 Land Capability Class I: It is observed that 1.0 ac is occupied by class I Almost entire area under this class has slope less than 0-1 per cent. Deep soils exist with clay loam as the dominant surface textural classes.

2.3.2 Land Capability Class III: The highest per cent of area (42.05) is under this class, found mostly near the factory and building side. Around fifty per cent of land in this class has slopes ranging from 5-10 per cent while the rest fall in the slope group of less than 5 per cent. Soils are shallow and gravelly in nature with erosion being relatively moderate.

2.3.3 Land Capability Class IV:, Land under this class is distributed in different pockets of the HUL area covering an area of 2.75 ac. It is mostly encountered in the middle reaches of the watershed. Clay loam are the predominant soil textural classes and shallow soil depth is the major root zone limitation. Slope of this class ranges from 10-15 & 15-25 per cent with severe erosion hazards.

2.3.4 Land Capability Class VI: A small portion of (0.89 ha) of the HUL area comes under this class.

2.3.5 Land Capability Class VII: The second highest per cent of area (30.11) is under this class, found mostly in lower side of the HUL area. Around this class has slopes ranging from 33-50 per cent. Soils are shallow depth and gravelly in nature with erosion being relatively very severe.

3.0. Soil remediation process

It was learnt from the report (Protocol for Remediation of Mercury submitted by NEERI, the soil remediation involves following processes.

- Preparation and Implementation of health and safety plan
- Site preparation
- Excavation of contaminated soil
- Stockpiling of excavated soil
- Soil washing
- Thermal retorting of fine / high mercury concentration soil
- Analysis of remediated soil
- Backfilling of remediated soil
- Decontamination / disposal of buildings and structures
- Validation of Site Remediation

The excavation and secured land filling is an *ex-situ* method for remediation of hazardous waste contaminated areas. The contaminated soil is usually excavated, treated, transported and disposed off in a secured landfill system. The main component of soil remediation works will involve excavation of the shallow soils down to depths of 30 cm in Areas A, B and C. If required, further excavation shall proceed at 30 cm depth intervals, until a point where soil mercury concentrations are below 20 mg/kg. Impacted soils will be transported to the main plant area where remediation will comprise of soil washing followed by vacuum retorting. The entire site of HUL is covered with thick vegetation and population of trees. Hence, excavation of soil may disturb the ecology of the site. In addition, it may lead to soil erosion from the site. Considering the fragile ecosystem of the area, it is not advisable to excavate the soil in all areas.

4.0. Methodology of soil erosion study

Study area was inspected by study team and the information on soil type and depth, land use pattern were generated. Contour survey at 1m grid was conducted and slope map was prepared. Rainfall and wind velocity data for 10 years period was collected from India Meteorological Department, Chennai and data was analyzed. Nature of vegetation and root distribution system was also examined for stability of erosion. Soil depth study was conducted in 30 locations randomly selected. The information was also generated based on discussion with officials of the Hindustan Unilever Limited and Environmental Resource Management. Mercury distribution and steps involved in soil remediation process was taken from previous reports submitted by NEERI and URS. The major problems expected during the soil excavation and backfilling process were identified and preventive measures to be followed are suggested.

5.0. Effects of soil remediation process on soil and vegetation

5.1. Effect of rainfall

The annual rainfall data (2000-2009) of Kodaikanal area (Fig.1.) shows that the average annual rainfall is 1812 mm. The North-East monsoon accounts for about 43 per cent (769 mm) of total rainfall followed by 20 per cent (359 mm) during the South-West monsoon and 37 per cent (142 mm) during summer and winter. The month of October receives

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highest rainfall followed by November and September whereas the months of January and February receive lowest rainfall. The maximum daily rainfall received during the period was 500 mm during May, 2006. Hence, maximum erosion is expected while excavation and backfilling of soil during the months of May, August, September, October and November.

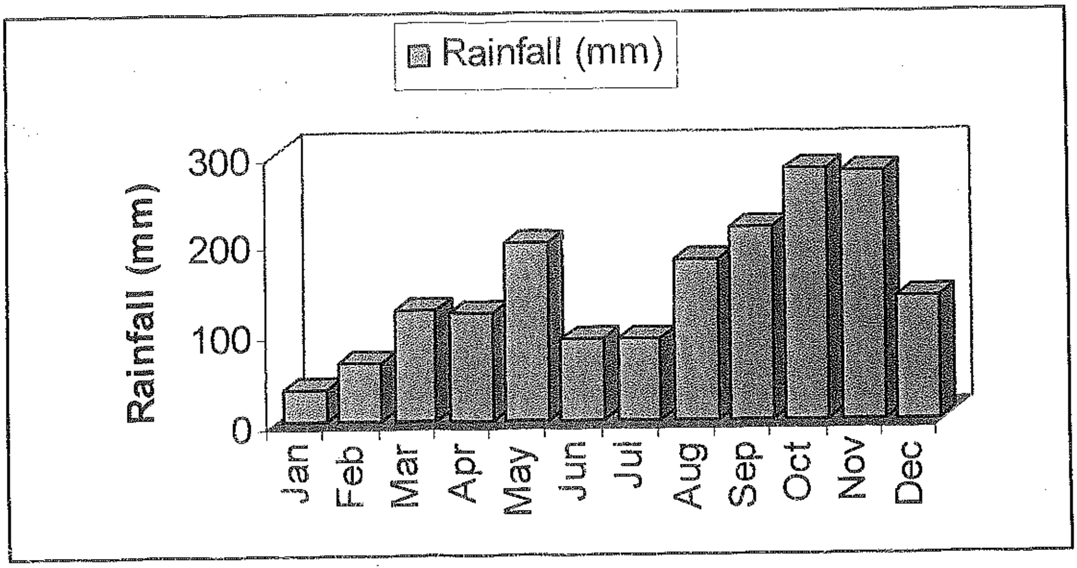


Fig. 1. Mean monthly rainfall of Kodaikanal (2000-09)

5.2. Effect of wind velocity on trees

The mean monthly wind velocity is highest during January (10.1 km hr^{-1}), December (9.42 km hr^{-1}) and February (9.0 km hr^{-1}) and lowest during September (6.0 km hr^{-1}). The maximum Wind velocity occurs (70 Km hr^{-1}) during May, 2006 and the overall mean wind velocity was observed is 7.8 Km hr^{-1}). There is the possibility of damages to the trees existing in the site due to excavation of soil and shallow root distribution combined with heavy wind speed during the months of December, January, February and March.

Table 2. Mean daily wind velocity at HUL site, Kodaikanal

Months	Daily mean velocity (km/hour)
January	9.63
February	9.00
March	8.90
April	8.15
May	6.95
June	6.43
July	6.86
August	6.19
September	6.00
October	6.22
November	8.30
December	9.42

5.3. Effect of Soil type and depth

Area A: In most of the places, stones and rubbles are found in the soil surface. The soil depth is shallow i.e soil depth $\leq$ 0.35 m, out of which the top fertile soil along with leaf litter is 0.20 m deep and the sub-soil depth is only 0.10 to 0.20 m. The parent rock is chornokite.

Area B: In most of the places, stones and rubbles are noticed on the soil surface. The soil depth is shallow i.e soil depth $\leq$ 0.40 m., out of which the top fertile soil along with leaf litter is 0.20 m deep and the sub-soil depth is only 0.20 m. The parent rock is chornokite.

Area C1: The soil depth is $\leq$ 0.50 m., out of which the top fertile soil along with leaf litter is 0.30 m and the sub-soil depth is > 0.20 m. The parent rock is chornokite.

Area C2: The soil depth is > 0.60 m., out of which the top fertile soil along with leaf litter is 0.30 m and the sub-soil depth is > 0.30 m. The parent rock is chornokite. At present some stone terraces are in damaged conditions in few of the areas within Area C2.

5.4. Effect of Slope

Area A: This area has a slope ranging between 33 and 50 per cent (Map 2). A major portion of this area has steep slopes which may cause severe soil erosion and mass movement of soil when the top soil is disturbed. The eroded soil will be transported to nearby valleys and water bodies.

Area B: Generally, slope in this area is between 33 to 50 per cent which will cause the moderate to severe soil erosion when the top soil is disturbed.

Area C1: Area C1 has slope ranges from 6 to 10 per cent. Slight soil erosion may occur in this area when the vegetation is removed. There are also the possibilities of formation of rills in this area if backfilling is done without adopting suitable erosion control measures.

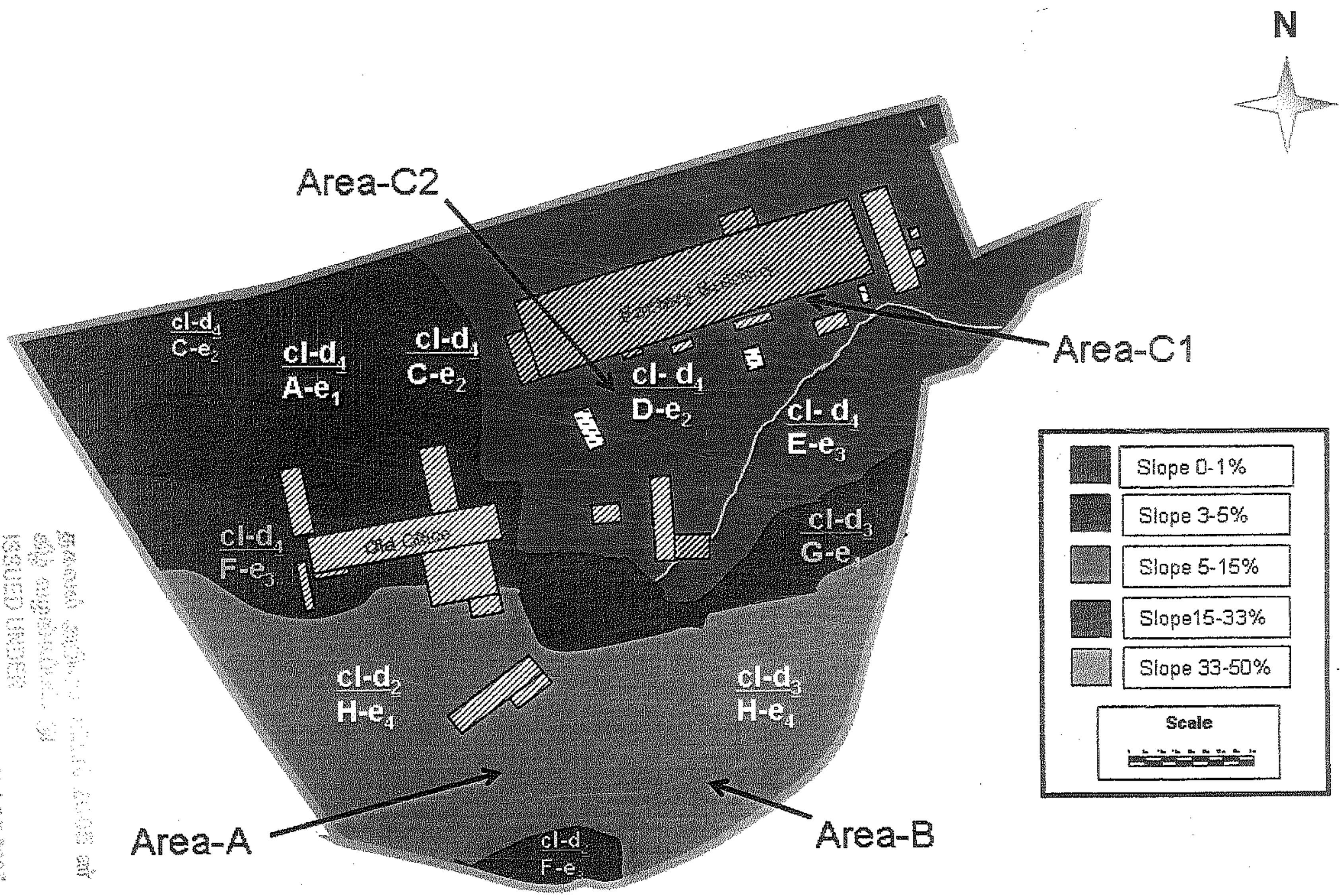
Area C2: General slope of this area is between 10 to 25 per cent which will cause the slight to moderate soil erosion and formation of rills.

5.5. Effect of Root distribution system of the trees

The root systems for most of the trees located at the site typically have shallow root distribution system. Effective root distribution systems vary from 1.0 to 3.00 m as mentioned in Table 3. The roots are distributed in shallow soil depth and even surface of the soil. Therefore, there is a possibility of trees falling while excavating soil near trees within the specified radius as indicated in Table 3.

Table 3. Effective root distribution system of various tree species at Mercury contaminated site of HUL, Kodaikanal

Sl. No	Name of the species	Radius of root distribution (m)
1	Eucalyptus	2.00-3.00 m
2	Ber	1 m
3	Cybrus	1 m
4	Casuarina	1.5 m
5	Katti Sali (Local name)	1.0 m



Map 2: Slope map of Hindustan Unilever Limited factory site at Kodaikanal

6.0. Expected problems while excavating soil and backfilling process

6.1. Area A

The following problems are identified while excavation of mercury contaminated soil and backfilling the treated soil in area 'A' based on the field observations and analysis of soil, slope, land use, rainfall and wind speed data.

- There is the possibility of soil erosion due to steeper slope (33 to 50 per cent) coupled with high intensity of rainfall and high surface runoff.
- Soil depth is shallow $\leq$ 0.25 m and the rocky batches will be exposed if the soil is excavated up to the depth of 25 cm, resulting in the possibility of movement of mass soil towards valley side. Soil depth is up to 0.3 m in few patches of this area where limited soil can be excavated up to 0.20 m but backfilling cannot be done due to deep slope in this area.
- Shallow rooted trees which exist in this area may fall down, even if 30 cm soil is excavated due to heavy wind (6.0 to 9.6 km / hr) and shallow distribution of root system.
- Backfilling of the soil is not possible in this area due to steep slope and shallow soil depth. As a result of the soil washing process, the cohesion and adhesion properties of soil will be washed away through water. If backfilling of the soil is done after washing, the soil will not stand over the bed rocks since continuous water lubrication will exist between backfilled soil and parent rock (Due to less compactness in backfilled soil, critical slope and accumulation of leaf litter on the top surface).
- Soil conservation measures such as Bench Terraces which may normally be adopted in such areas cannot be possible due to shallow soil depth and high gravel content of the soil.

6.2. Area B

The following problems are identified in area B.

- There is the possibility of soil erosion due to steeper slope (33 to 50 per cent) coupled with higher intensity of rainfall and higher runoff.

- Soil depth is moderate ≤ 0.40 m and excavation of soil should be restricted up to 0.30 m depth.
- Shallow rooted trees which are exists in this area may fall down, even if 30 cm soil is excavated due to heavy wind (6.0 to 9.6 km / hr) and shallow distribution of root system. Hence, excavation near the trees up to 3 m radius should be avoided.
- Backfilling of the soil is possible in this area where flat land is available and in sloppy area, only excavation can be done and backfill the soil in C area.
- Soil conservation measures such as Bench Terraces which will be normally adopted such areas cannot be possible due to shallow soil depth and high gravel content of the soil.

6.3. Area C1

Based on field observations the following problems were identified in Area C1.

- Moderate land degradation due to soil erosion on slope i.e ≥ 10 to 20 per cent and high runoff
- Excavation of soil can be done maximum up to 0.35 m due to moderate soil depth ≤ 0.45 m
- Backfilling the treated soil without soil conservation measures may cause severe soil erosion.
- Removal of top soil which contains organic carbon while excavation and backfilling process may bring the land to low productivity.

6.4. Area C2

Based on field observations the following problems were identified in Area C2.

- Soil depth is deep which is having more than 0.60 m may cause soil erosion due to slope land i.e ≥ 6 to 10 per cent
- Improper terrace system and retaining wall may also cause soil erosion during heavy storm events.
- Low land productivity due to loss of vegetation

7.0. Proposed conservation measures to be carried out while undertaking soil remediation process

Keeping in view of high rainfall during the months of May, August, September, October and November, the excavation and backfilling may be attempted during the Months of December to April, June and July. Heavy wind speeds are encountered during the months of January to April, hence proper care needs to be taken while excavating the soil near the trees. In general where the trees are located in dense or close spacing, excavation of soil should be completely avoided. At other places, for specified distances as given in Table 4, the soil should not be disturbed.

Table 4. Recommended distances from the major trees where soil should not be disturbed

Sl. No	Name of the tree	Radius of soil not to be disturbed around the trees (m)
1	Eucalyptus	3.00 m
2	Ber	1 m
3	Cybrus	1 m
4	Casuarina	1.5 m
5	Katti Sali (Local name)	1.0 m

7.1. Area A

This is a critical zone where depth of soil is very shallow $\leq$ 0.25 m, slopes are steep (33 to 50 per cent) and some of the patches the parent rocks are exposed. If soil is backfilled in this area, the soil could potentially be washed away in heavy rain events due to its reduced binding capacities and steep slopes. The estimated soil loss would be varies from 45 to 50 tonnes / ha / year. Hence, the following conservation measures are recommended in this area.

- It is suggested to not to disturb the soil where the steep slope area having above 50 % land slope. Instead, in-situ measures should be taken up to avoid the movement of mercury contaminated soil from this area to neighboring areas (Map 4).
- Covering with Geo-Jute blankets and planting grass species will be the suitable option to avoid the soil movement.
- Gabion type of support wall may be constructed on the lower portion of the area over a length of 150 m which will not allow the mercury contaminated soil to spread over other areas in future. The boulders which are already available in the site can be used for this purpose.
- In part of this area behind scrap yard, excavation of soil may be restricted to 25 cm depth and backfill the washed soil in Area C2. While excavating in the leveled portion of this area, terrace system may be followed with 2:1 slope (Map 4). Riser part may be maintained with 1:1 slope ratio. Riser part may be covered with Geo-Jute erosion control blanket and grass roots may be planted.
- In parts of the area (level surface) where soil can be excavated up to 20 cm depth, immediate backfilling is recommended by filling external soil. Necessary quantity of soil may be excavated from the residential quarters located within the premises and filled in this area followed by immediate grass turfing.

7.2. Area B

The following erosion control measures have to undertaken while excavating the soil and backfilling process in the area "B".

- In parts of the area nearby trees, immediate filling is recommended by filling external soil. Necessary quantity of soil may be excavated from the area of residential quarters located within the premises and filled in this area followed by immediate grass turfing. The excavated soil in these patches may be treated and backfilled in area C1 and C2.
- Stone bunds at 0.5 m vertical interval may be constructed in slope area where trees are available to avoid soil erosion. The boulders which are already available in the site may be utilized.

- It is suggested that Gabion type of supporting wall on the lower portion of the area "B"over a length of 150 m which will not allow the contaminated soil to spread to over other areas (Map 4).
- It is proposed to construct Random Rubble Stone Masonry Check Dam (RRCD) in the lower portion of the gully located in between area A & area B (Map 4).
- Gabion Check Dam (GCD) on the upper portion of the gully may be constructed to collect the eroded soil which will be washed with runoff after immediate backfilling. This soil can be desilted and it can be spread over the areas in future time.

7.3. Area C1

- Excavation of soil may be restricted up to 0.35 m in this area.
- Soil may be excavated by forming terraces and terrace support walls may be constructed in each terrace.
- It is suggested that Terrace support wall over a length of 365 m (Including all terraces) is suggested / repair of existing terrace support wall over a length of 280 m (Including all terraces) is suggested to hold the filled soil on benches and it will not permit erosion.
- Root slips of the Vegetative barriers viz. Guatemala (*Tripsacum laxum)* and Kikyu *(Pennisetum clandestinum)* should be planted at recommended spacing on terrace after backfilling the treated soil to control erosion.
- In slope area nearby factory building, soil may be excavated at 1:1 slope ratio and turfing of Kikyu grass *(Pennisetum clandestinum)* may be laid out.
- Drainage lines passing through this area may be treated with three numbers of loose boulders check dam with trapezoidal section.
- Treated soil from area A & B may be refilled in this area by raising the lower level terraces.

7.4. Area C2

- Excavation of soil should not exceed the depth of 0.6 m in this area. In vertical slope area nearby factory building, the excavation may be restricted to a depth of 0.30 m.
- Soil may be excavated by forming terraces and terrace support walls may be constructed in each terrace.
- It is suggested to construct the Terrace support walls over a length of 350 m (All terraces) / repair of existing terrace support wall over a length of 215 m (All terraces) to hold the filled soil on benches and control the erosion during post filling period.
- Root slips of the Vegetative barriers viz. Guatemala (*Tripsacum laxum)* and Kikyu *(Pennisetum clandestinum)* should be planted at recommended spacing on terrace after backfilling the treated soil to control erosion.

8.0. Technical details of conservation measures to be adopted during excavation and backfilling process

8.1. Gabion support wall

Gabion Support Wall has been successfully used in India and elsewhere for controlling soil erosion. Gabions are woven wire boxes, filled with stones / boulders. These structures retain debris and soil without impounding of water and thus support growth of natural vegetation. Gabions have fairly long life (20-25 years), flexible (bend without breaking), porous (water can seep through them), stable, economical and simple to construct. They are permeable to water but retain soil/debris and act as self draining units, thus relieve hydrostatic pressure. Since these Gabion units are heavy, they are able to withstand earth thrust and with time become a solid mass due to silt deposition in pores and helps in establishment of vegetation. Boxes can be woven at site or easily transported to the site in flat folded condition and filled. The construction of gabion structures is simple and can be done by unskilled labour themselves with a little experience or guidance.

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The materials are reusable if the structure failed due to rusted GI wire or due to deformation and can be easily repaired/strengthened by adding additional boxes if needed. Construction of gabion structures require wire knitted boxes or cages (ie. fabrication of gabion boxes) and laying at sites, filling with stones or boulders and joining or tying of individual boxes. Gabion boxes can be fabricated at site using Galvanised iron (GI) wire of 8 to 10 gauge thickness. The woven wire boxes serve as unit block for constructing gabion structures and these may be made of any convenient size. Gabion empty units are placed in position according to the plan in a foundation having a depth of 0.5 to 0.75m and tied together and kept ready with their sides top and flaps in the correct position by stretching to provide alignment after the boxes are tied together. All the required units are placed and tied to each other firmly, so that the whole structure acts as a single unit.

Gabion support wall in lowest portion of the Area 'A' for a length of 150 m is suggested to prevent the movement of mercury contaminated soil to other neighboring areas. The design and estimate for Gabion support wall is given in Annexure I.

8.2 Loose boulder Terrace support wall (LBTSW)

A total length of 700 m of terrace support wall is suggested in area C1 and C2 to support the terraces filled with treated soil. Terrace support wall for check the scouring or undercutting to protect erosion of fields and side slopes in which near/side by area will not get damaged during rainy season. The design and estimate of loose boulders terrace support wall is given in Annexure II.

8.3 Random rubble masonry check dam (RRCD)

Random Rubble Masonry Check Dam is suggested on the bottom most valley point in between Area A and Area B sites. The design and estimate for constructing one number of RRCD is given in Annexure III.

8.4. Gabion Check dam (GCD)

Three numbers of gabion check dams are suggested in drainage line passing through area C2 and Area B as shown in map 4. Construction of gabion structures require wire knitted boxes or cages (ie. Fabrication of gabion boxes) and laying at sites, filling with stones or boulders and joining or tying of individual boxes. Gabion boxes can be fabricated at site using Galvanized iron (GI) wire of 8 to 10 gauge thickness. Gabion empty units are placed in position according to the plan in a foundation having a depth of 0.5 to 0.75m and tied together and kept ready with their sides top and flaps in the correct position by stretching to provide alignment after the boxes are tied together. All the required units are placed and tied to each other firmly. The design and estimate for one number of GCD is given in Annexure IV. Totally three numbers are required to be constructed as shown in Map 4.

8.5. Loose boulders check dam

Three numbers of loose boulder check dams may be constructed(as shown in Map 4) by using loose boulders for a length of 3 m, 0.8 height (Below ground level- 0.3 m) and width of 0.7 m in upper reaches of drainage line in Area C1. The horizontal interval between each check dam should be 20 m. Estimate for one number of loose boulders check dam is given in annexure V.

8.6. Stone bunding

Stone bunding is the simple loose boulder stone wall arranged on contour at 0.5 m vertical interval at a height of 0.6 m. Use of grasses on upstream side of stone bunds are very common practice as it provides better stability to stone bund. To improve its conservation efficiency during initial years, one or two rows of grass need to be planted. This structure is essential in area B. The estimate and design is enclosed as Annexure VI.

8.7. Grass Turfing

The critical slope on the riser is $\leq 35^{\circ}$ behind the factory building, hence there is possible of severe erosion during rainy season due to insufficient compactness of the soil. Therefore, riser part behind the factory building has to be protected by spreading a thick layer/ bunch of locally available grasses. In general while removing soil on the riser portion nearby building side should be maintained with 1:1 or 1½: 1 slope. Some of the grasses may include *Chrysopogon fulvus, Cymbopogan spp., Eragrostis curvula (weeping love), Pennisetum clandestinum, Cynodon dactylon, Saccharum spp.* etc.

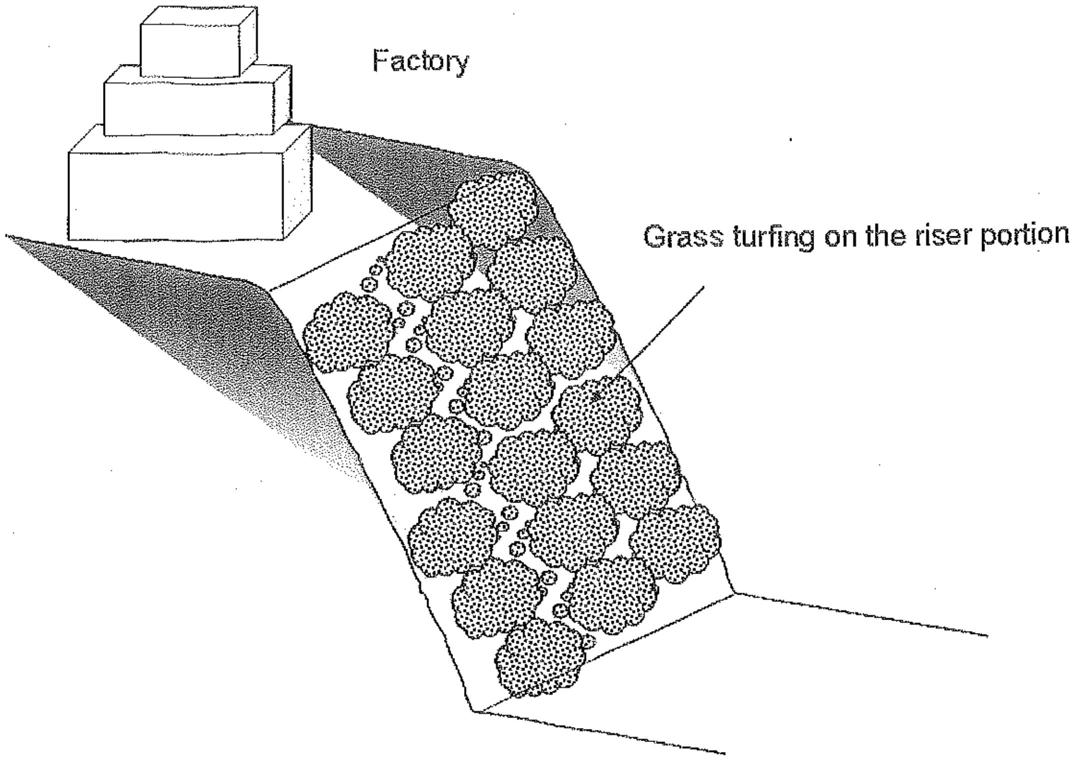


Fig. 2 Grass Turfing on riser portions behind factory building of HUL

8.8. Grass planting

Locally available grasses such as *Chrysopogon fulvus,, Cymbopogan spp., Eragrostis curvula (weeping love), Pennisetum clandestinum, Cynodon dactylon, Saccharum spp.* may be planted after backfilling the soil which will hold the soil and does not permit erosion during rainy season.

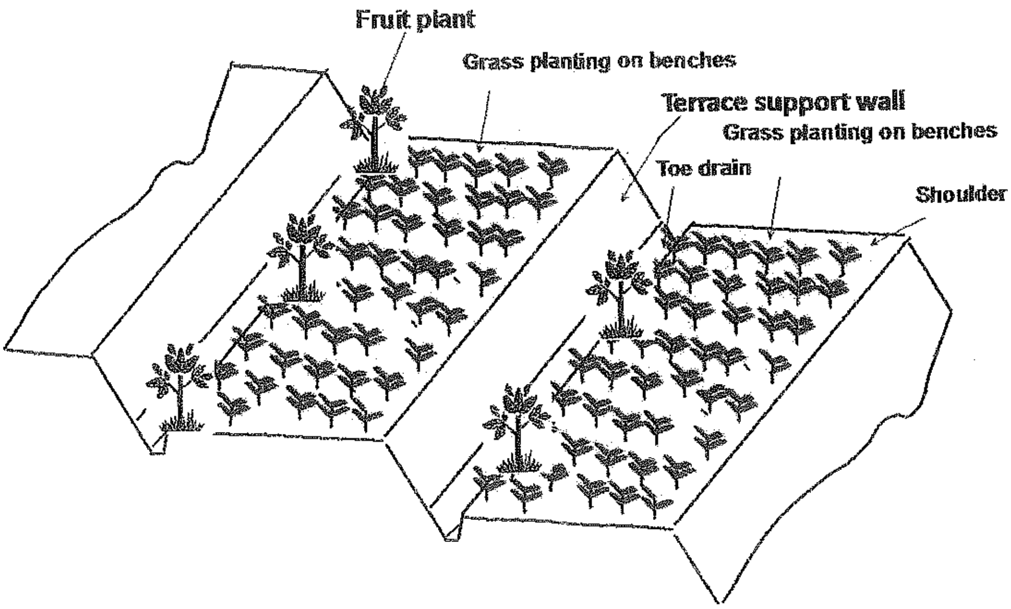


Fig. 3 Grass planting in terraces in area C1 and C2 after backfilling the soil

8.9. Geo-jute layering with grass plantation

Geo-jute (also called 'soil saver') blanket is a natural geo-textile. This is essentially a jute matting with an open mesh of 2 to 5 mm thick jute yarn having 10 mm apertures and is biodegradable. It has been successfully tried for stabilization of landslides, mine dumps and constructed slopes. It was successful in mine spoil rehabilitation at Sahastradhara, Dehradun by afforestation on affected areas. The technique of geo-jute application included (a) spreading of geo-jute by overlapping and joining adjacent widths, (b) driving wooden sticks to a depth of 0.5 m to secure matting in place, (c)planting rooted slips of local grasses and cuttings of bushes in openings between the geo-jute strands at close spacings. It was found successful for initial establishment of vegetation on degraded slopes (upto 60 - 70%). This technology is recommended for slope land in area A & B including riser part of terraces nearby canteen.

8.10. Contour vegetative barriers

In area 'C1', where the trees are available, vegetative barriers viz. Goutamala grasses in two rows may be planted after backfilling of soil as shown below:

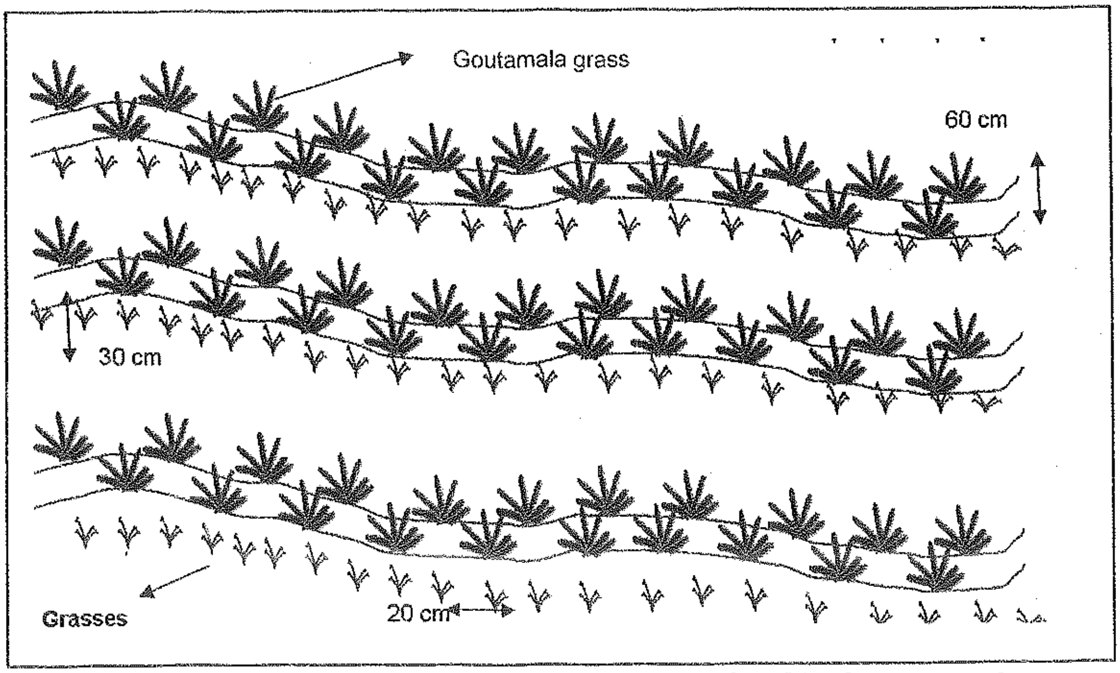
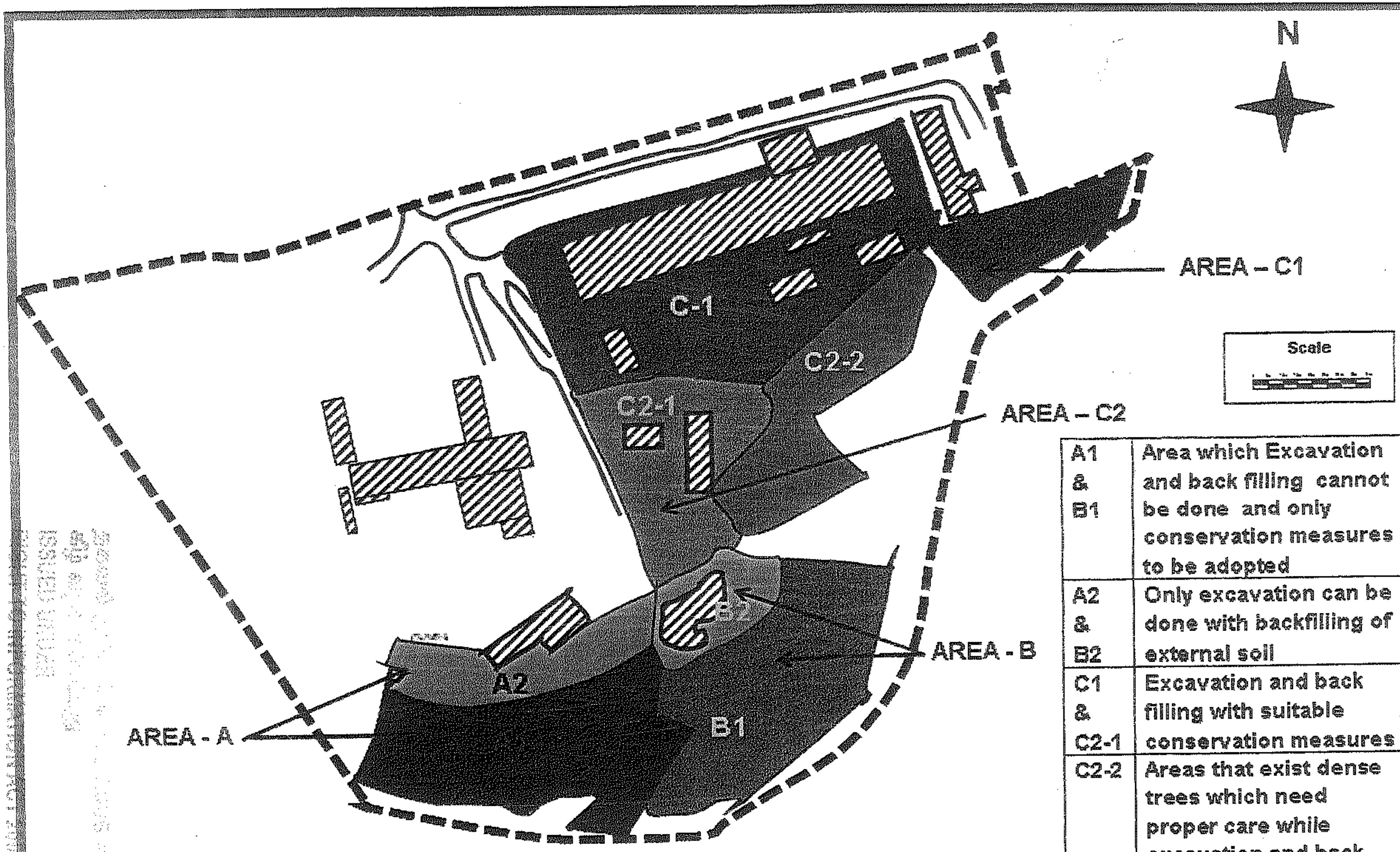
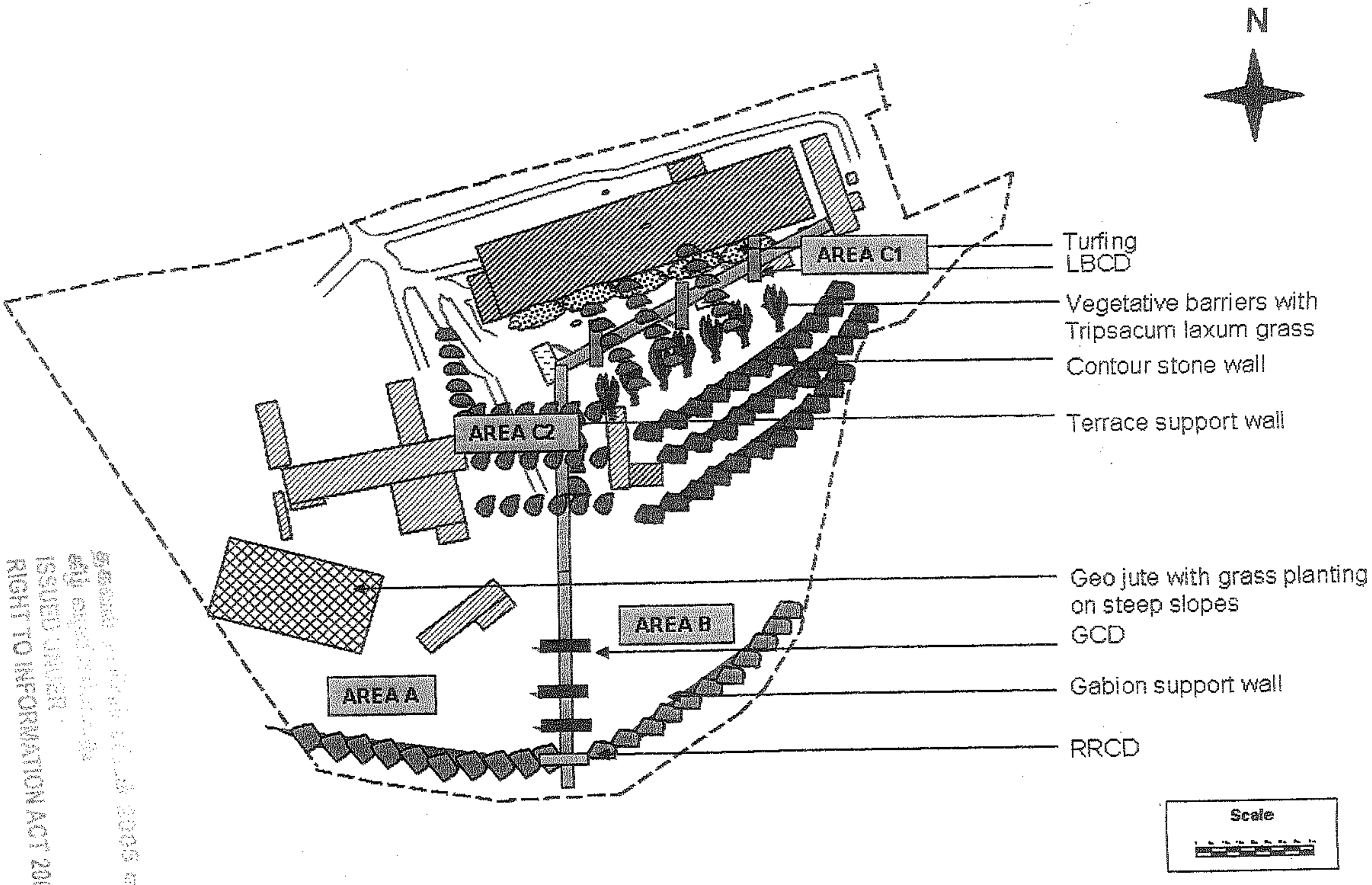


Fig 4. Contour vegetative barriers in area 'C1' in between trees



A1 & B1	Area which Excavation and back filling cannot be done and only conservation measures to be adopted
A2 & B2	Only excavation can be done with backfilling of external soil
C1 & C2-1	Excavation and back filling with suitable conservation measures
C2-2	Areas that exist dense trees which need proper care while excavation and back filling .

Map 3: Delineated area for conservation measures



Map 4: Map showing the proposed conservation measures

9.0. Summary of Recommendations

- Keeping in view of high rainfall during the months of May, August, September, October and November, the excavation and backfilling may be attempted during the Months of December to April, June and July. Heavy wind speeds are encountered during the months of January to April, hence proper care needs to be taken while excavating the soil near the trees.
- Keeping in view of steep slope, high rainfall, and shallow soil depth and existing of trees, excavation should be avoided in Area 'A'. Excavation and backfilling can be done in part of the Area 'B' and Area C1 and C2 (As demarked in Map 3) with suitable erosion control measures as recommended in sections 7 and 8.
- In general where the trees are located in dense or close spacing, excavation of soil should be completely avoided. At other places, for specified distances as given in Table 4, the soil should not be disturbed.
- It is suggested to not to disturb the soil where the steep slope area of 'A' Zone (as demarked in Map 3) having above 50 % land slope. Instead, in-situ measures should be taken up to avoid the movement of mercury contaminated soil from this area to neighboring areas. Covering with Geo-Jute blankets and planting grass species will be the suitable option to avoid the soil movement.
- Gabion type of terrace support wall may be constructed on the lower portion of the area 'A' over a length of 150 m which will not allow the mercury contaminated soil to spread over other areas in future. The boulders which are already available in the site can be used for this purpose.
- In part of the area 'A' (below canteen), excavation of soil may be restricted to 25 cm depth and backfill the washed soil in Area C2. While excavating in the leveled portion of this area, inward terrace system may be followed with 2:1 slope. Riser part may be maintained with 1:1 slope ratio. Riser part may be covered with Geo-Jute erosion control blanket and grass roots may be planted.
- In parts of the area 'A' (Only leveled portion where there is no trees) and area 'B' (Near the tress) where soil can be excavated up to 20 cm

depth, immediate backfilling is recommended by filling external soil. Necessary quantity of soil may be excavated from the residential quarters located within the premises and filled in this area followed by immediate grass turfing. The excavated soil in these patches may be treated and backfilled in area C1 and C2.

- Stone bunds at 0.5 m vertical interval may be constructed in slope area where trees are available to avoid soil erosion in Area 'B'. The boulders which are already available in the site may be utilized.
- It is suggested that Gabion type of retaining wall on the lower portion of the area "B" over a length of 150 m which will not allow the contaminated soil to spread to over other areas.
- It is proposed to construct Random Rubble Stone Masonry Check Dam (RRCD) in the lower portion of the gully located in between area A & area B.
- Gabion Check Dam (GCD) on the upper portion of the gully may be constructed to collect the eroded soil which will be washed with runoff after immediate backfilling. This soil can be desilted and it can be spread over the areas in future time.
- In area 'C1", Excavation of soil may be restricted up to 0.35 m depth.
- Soil may be backfilled by forming terraces and terrace support walls may be constructed in each terrace.
- Root slips of the Vegetative barriers viz. Guatemala (*Tripsacum laxum)* and Kikyu *(Pennisetum clandestinum)* should be planted at recommended spacing on terrace after backfilling the treated soil to control erosion in Area C1 and C2.
- In slope area nearby factory building, soil may be excavated at 1:1 slope ratio and turfing of Kikyu grass *(Pennisetum clandestinum)* may be laid out.
- Drainage lines passing through the area C1 and C2 may be treated with three numbers of loose boulders check dam with trapezoidal section.
- In area C2, Excavation of soil should not exceed the depth of 0.6 m in this area. In vertical slope area near factory building, the excavation should be restricted to a depth of 0.30 m.

ANNEXURES

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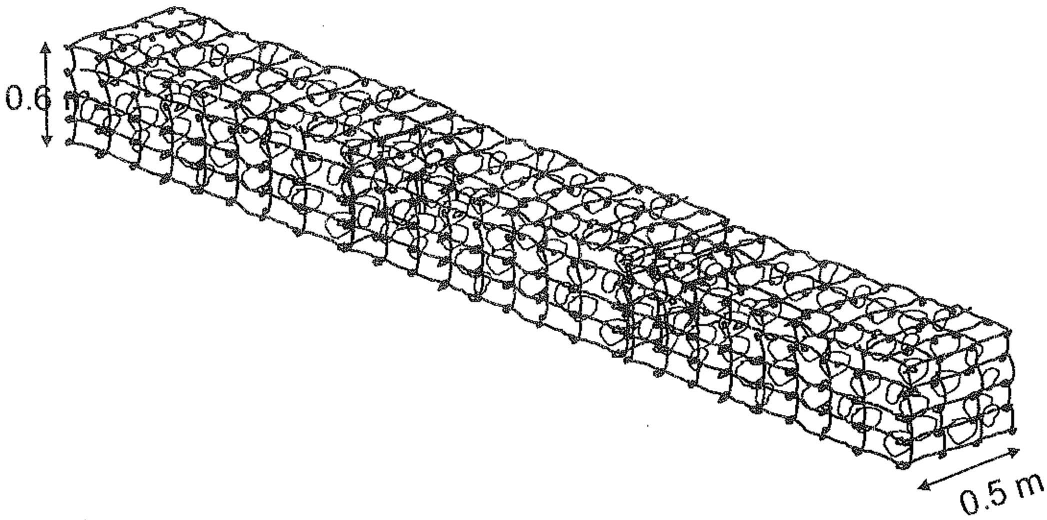
Annexure I

Design and estimate for Gabion support wall

Abstract estimate for constructing Gabion support wall for 150 rm in Area 'A'

SL. No	Descriptions of work	Qty	Rate	Amount (Rs.)
1	Earth work	15	40	600
2	Wire netting	330	8.5	2805
3	Cost of gabion wire @ 1.28 kg/sqm	423	65	27495
4	Dry stone masonry	45	650	29250
5	Rough stone dry packing	10	650	6500
6	Unforeseen item, if any			733
	Total			**67383**



Drawing of Gabion support wall

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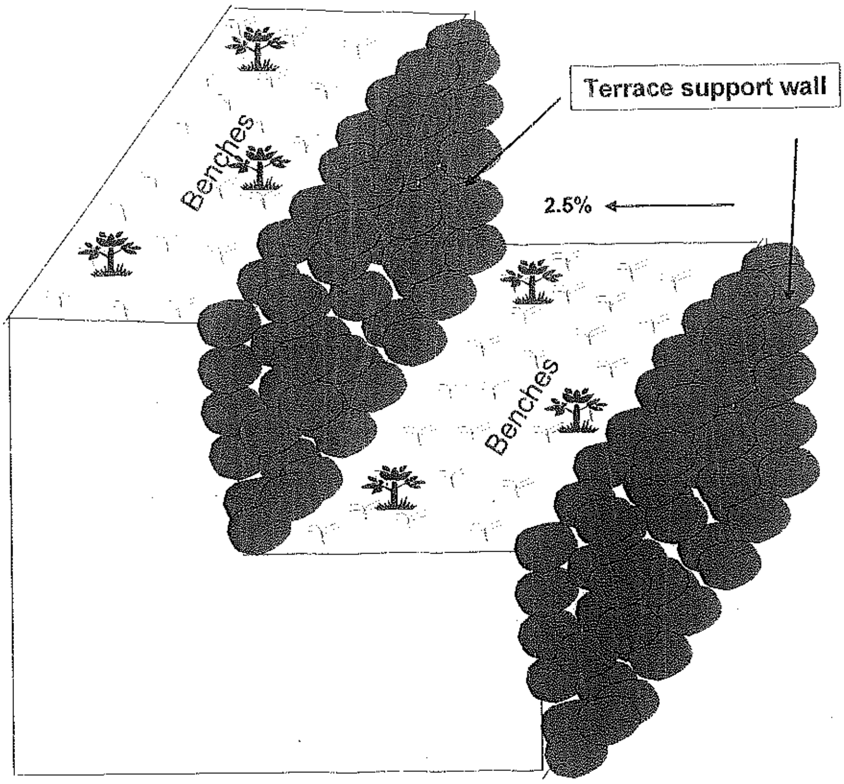
Annexure II

Design and estimate for loose boulder terrace support wall

Abstract estimate for constructing loose boulder terrace support wall for 700 rm in Area C1 and C2

S.No	Descriptions of work	Qty	Rate	Amount (Rs.)
1	Earth work	70 cum	40	2800
4	Dry stone masonry	126 cum	150	18900
6	Unforeseen item, if any			700
	Total			**22400**



Drawing of Terrace support wall

Annexure III

Design and estimate for loose Random Rubble Masonry Check Dam (RRCD)

Detailed estimate for constructing Random Rubble Masonry Check dam in drainage line passing through Area 'A' and 'B'

Sl. No.	Description of work	No.	L (m)	B (m)	D(m)	Quantity	Unit
I	**Earth work for foundation**						
1	Head wall+Head wall extension	1	8	1.0	1.1	8.80	cum
2	Up stream side wall	2	2	0.75	1.0	3.00	cum
3	Down stream side wall	2	2	0.75	1.0	3.00	cum
4	Toe wall	1	4	0.3	0.6	0.72	cum
5	Apron	1	4	1.6	0.2	1.28	cum
	Sub-total					**16.80**	**cum**
II	**Cement concrete 1:4:8 using 40 mm Blue metal**						
1	Head wall+Head wall extension	1	8	1.0	0.2	1.60	cum
2	Up stream side wall	2	2	0.75	0.2	0.60	cum
3	Down stream side wall	2	2	0.75	0.2	0.60	cum
4	Toe wall	1	4	0.3	0.8	0.96	cum
5	Apron	1	4	1.6	0.2	1.28	cum
	Sub-total					**5.04**	**cum**
III	**Random Rubble Masonry in CM 1:4**						
a	**Below ground level**						
	Head wall+Head wall extension	1	8	1.0	0.9	7.20	cum
	Up stream side wall	2	2	0.6	0.8	1.92	cum
	Down stream side wall	2	2	0.6	0.8	1.92	cum
	Sub-total					**11.04**	**cum**
b	**Above Ground level**						
	Head wall+Head wall extension	1	8	(1.0+0.45)/2	1.0	5.80	cum

	Head wall extension (top)	2	2	0.45	0.45	0.81	cum
	Up stream side wall	2	2	0.525	1.45	3.05	cum
	Down stream side wall	2	2.23	0.525	1.45	3.39	cum
	Sub-total					**13.04**	**cum**
	Total					**24.08**	**cum**
V	**Plastering**						
	Head wall+Head wall extension	1	8.9	0.6		5.34	sqm
	Up stream side wall	2	2	0.45		1.80	sqm
	Down stream side wall	2	2	0.45		1.80	sqm
	Toe wall	1	4	0.9		3.60	sqm
	Sub-total					**12.54**	**sqm**
VI	**Pointing**						
	Head wall+Head wall extension(U/S)	1	8		1.0	8.00	sqm
	Head wall+Head wall extension(D/S)	1	8		1.08	8.64	sqm
	Head wall extension (side)	2	2		0.45	1.80	sqm
	Up stream side wall	2	2		1.22	4.88	sqm
	Down stream side wall	2	2.23		1.22	5.43	sqm
	Sub-total					**28.75**	**sqm**

Abstract estimate for constructing Random Rubble Masonry Check dam in drainage line passing through Area 'A' and 'B'

Sl. No.	Description of work	Qty	Unit	Rate	Amount
1	Earth work for foundation	16.8	cum	56.00	940.80
2	Cement concrete 1:4:8 using 40 mm Blue metal	5.04	cum	2903.53	14633.79
3	Random Rubble Masonry in CM 1:4	24.08	cum	2589.00	62343.12
4	Plastering	12.54	sqm	169.70	2128.04
5	Pointing	28.75	sqm	169.70	4878.88
6	Unforseen items, if any @ 3%				2547.74
	Total for one RR Masonry CD				87472.36

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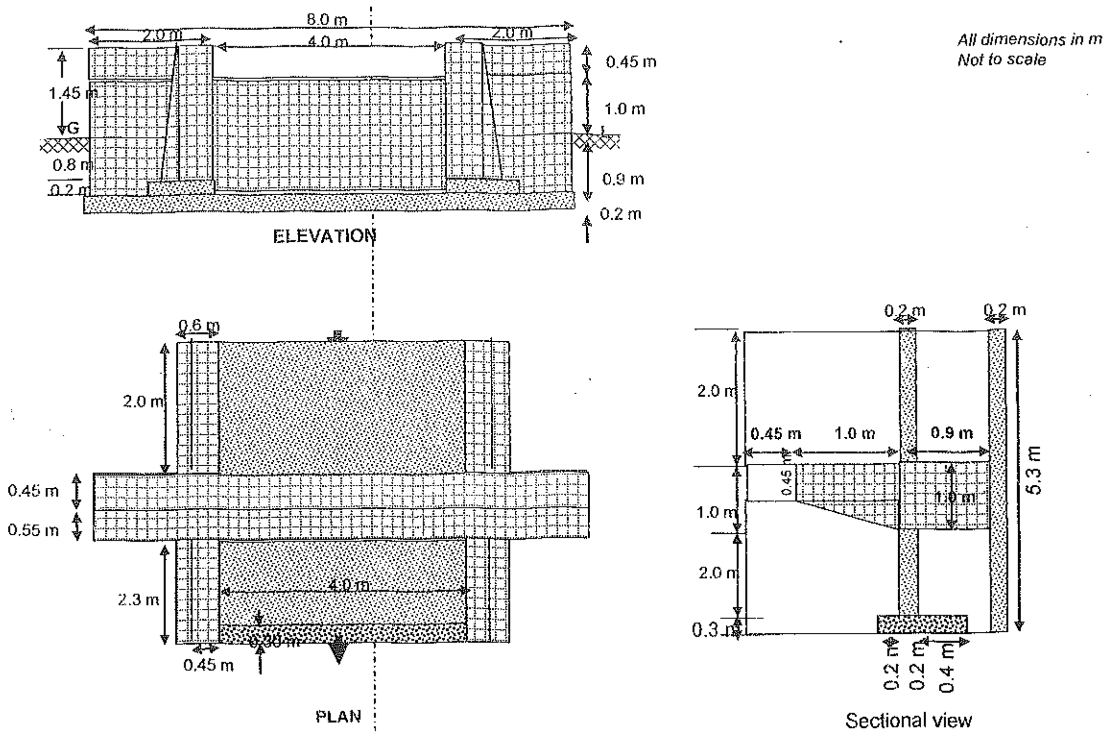
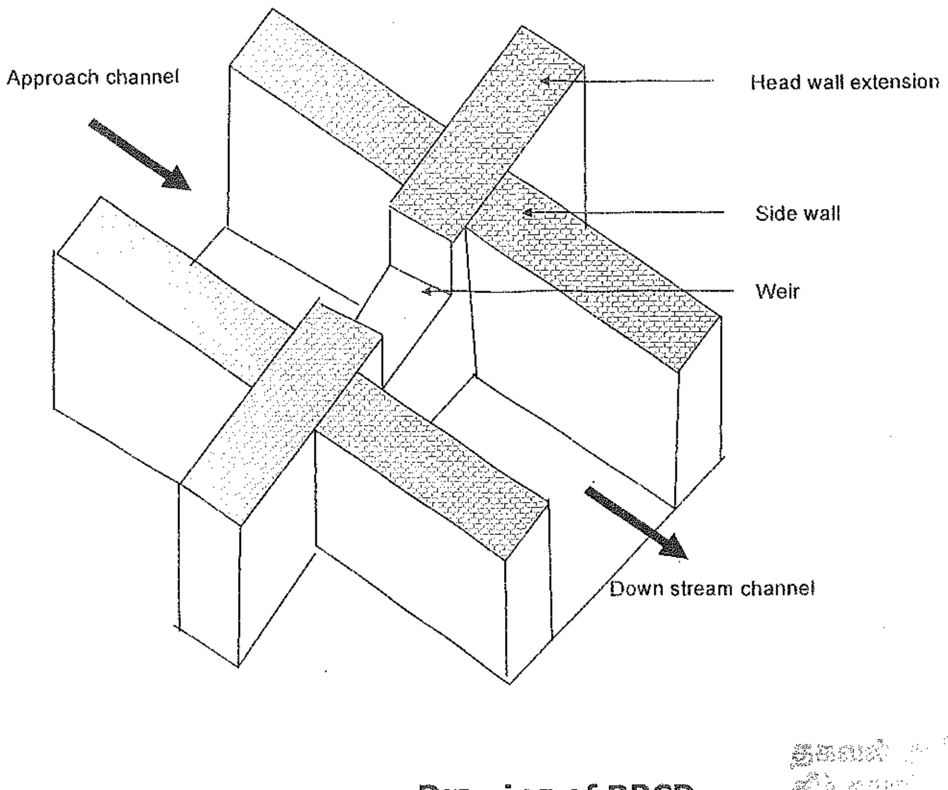


Drawing of RRCD in Drainage line passing through Area 'A' and 'B'



Drawing of RRCD

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Annexure IV

Detailed estimate for constructing Gabion Check Dam in HUL area at Kodaikanal

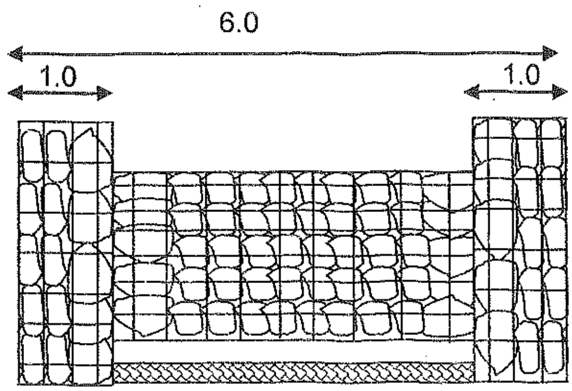
Sl. No.	Description of work	No.	L (m)	B (m)	D(m)	Quantity
1	Earth work excavation and depositing on bank within initial lead and lift in hard stiff clay stiff black cotton hard red earth shales murrams gravel stony earth mixed with small sized boulder and hard gravelly soil as per SS 20 B & SI 62.					
	For foundation					
	Body wall	1	6	1.2	0.8	5.76
	Upstream side wall	2	2	0.6	0.4	0.96
	Down stream side wall	2	2.6	0.6	0.4	1.248
	Toe wall	1	4	0.6	0.4	0.96
	Paving	1	4	2	0.2	1.6
	Sub-total					10.528
2	Supplying and fixing gabion boxes in 10 gauge GI wire with 10 cm x 10 cm opening including cost of mould labour charges for cutting etc. complete					
	Body wall					
	Bottom and top	2	6	1.2		14.4
	Front and back	2	6		2.2	26.4
	Earthern sides	2		1.2	2.2	5.28
	Vent sides	2		1.2	0.4	0.96
	Deduct vent	2	4		0.4	3.2
	Upstream side wall					
	Bottom and top	4	2	0.6		4.8
	Front and back	4	2		1.4	11.2
	Earthen sides	4		0.6	1.4	3.36
	Downstream side wall					
	Bottom and top	4	2.6	0.6		6.24
	Front and back	4	2		1.02	8.16
	Earthen sides	4		0.6	1.4	3.36
	Toe wall					
	bottom and top	2	4	0.6		4.8
	Front and back	2	4		0.7	5.6
	Earthen sides	2		0.6	0.7	0.84
	Sub-total					92.2
3	Dry stone masonry for the construction of gabion structures by using best quality of new stones from approved quarry with standard specifications					

	BGL					
	Body wall	1	6	1.2	0.8	5.76
	AGL					
	Body wall	1	6	1.2	1	7.2
	2	1	1.2	0.4	0.96	
	2	2	0.6	1	2.4	
	2	2.6	0.6	1	3.12	
	1	4	0.6	0.3	0.72	
	Sub total					12.96
4	Rough stone dry packing	1	4	2	0.2	1.6

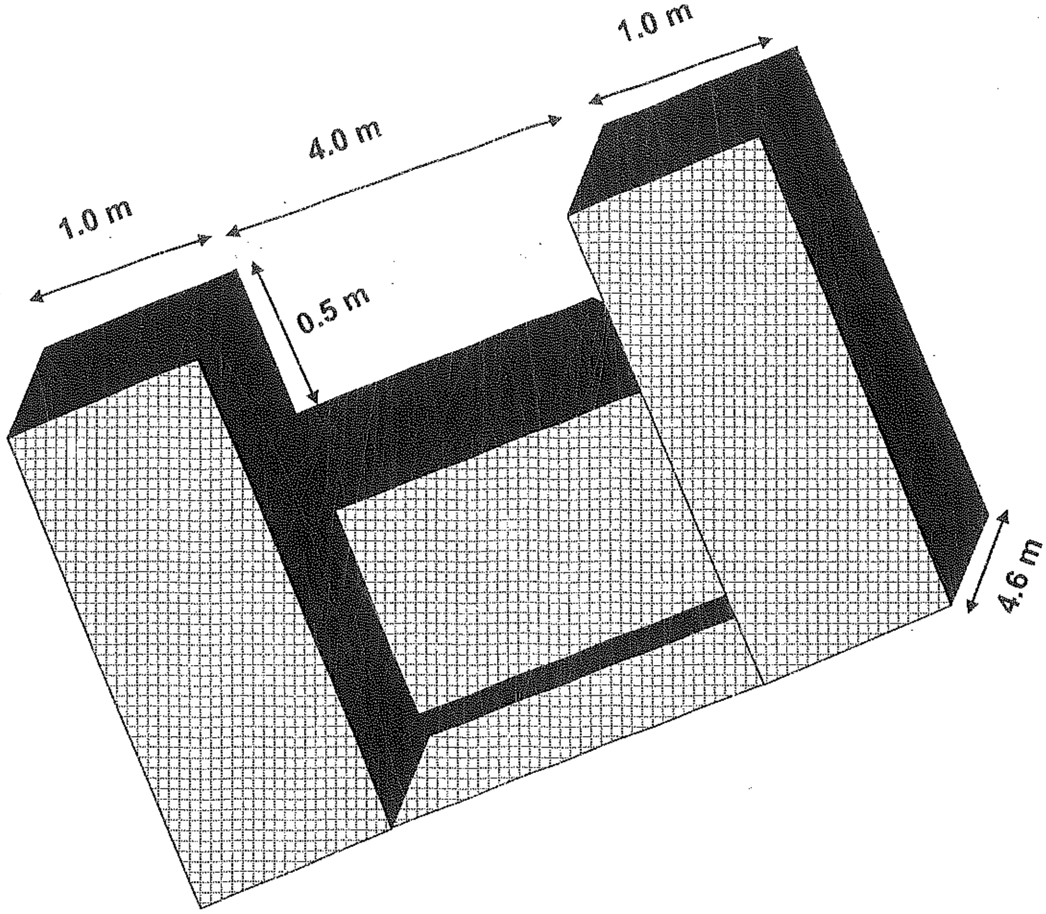
Abstract estimate for constructing Gabion Check Dam in HUL area at Kodaikanal

S.No	Descriptions of work	Qty	Rate	Amount (Rs.)
1	Earth work	10.528	40	421.12
2	Wire netting	92.2	8.5	783.7
3	Cost of gabion wire @ 1.28 kg/sqm	118	65	7670
4	Dry stone masonry	12.96	650	8424
5	Rough stone dry packing	1.6	650	1040
6	Unforeseen item, if any @3%			550
	Total for one Gabion Check Dam			**18889**

Not to scale
All measurements in m



Drawing of Gabion check dam



Isometric view of Gabion Check Dam with dimensions

Annexure V

Cost estimate of proposed LBCD at HUL site in Kodaikanal

S. No	Item	No	Length (m)	Width (m)	D/Height (m)	Quantity (cum/sqm)	Rate Unit	Amount (Rs)
1	Clearing grass and other over growth of vegetation and small trees of girth upto 30 cm and removal of rubbish upto a distance of 150 m outside the periphery of the area cleared		10	10		100	0.5235	52.35
2	Excavation in foundation in hard soil including depositing the excavated stuff in uniform layers as and where directed within a lead of 50 m and upto 1.5 m depth of excavation							
	Apron	1	0.75	3.50	0.3	0.788		
	Headwall	1	3.00	0.90	0.3	0.810		
	headwall extension	2	1.00	0.45	0.4	0.360		
	End silll	1	3.50	0.30	0.3	0.315		
						2.273	57.5	130.67
3	Dry rubble masonry using blasted rubble							
	including chips							
	Apron	1	0.75	3.50	0.30	0.788		
	Headwall(below G.L.)	1	3.00	0.70	0.30	0.630		
	Headwall(above G.L.)	1	3.00	0.58	0.50	0.863		
	headwall extension	2	1.00	0.45	0.40	0.360		
	End silll (below G.L.)	1	3.50	0.30	0.30	0.315		
	End silll (above G.L.)	1	3.50	0.30	0.15	0.158		
						3.11	607	1889.29
	Total							**2072.31**
	Contingency (10%)							127.69
	Grand Total							**2200.00**

Annexure VI

Estimate for constructing Stone bund for 500 rm in HUL area at Kodaikanal

S.No	Descriptions of work	Qty	Rate	Amount (Rs.)
1	Earth work	50	56	2800
4	Dry stone masonry	150	650	97500
6	Unforeseen item, if any @3%			650
	Total			**100950**
	Cost per rm			**Rs.202/-**

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PLATES

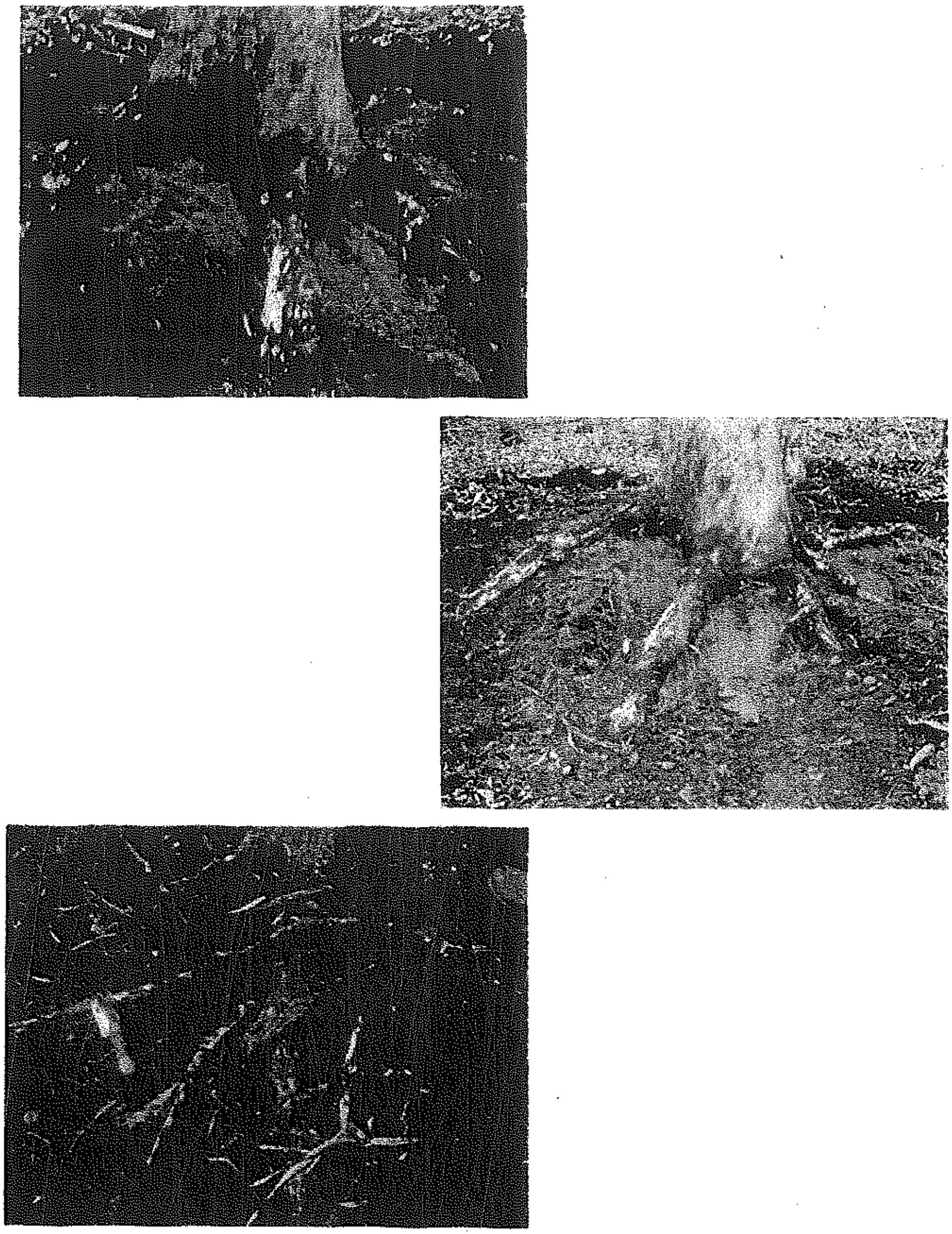

Plate 1: Shallow root distribution systems existing in study area

Plate 2: Forest area where stone bunds are proposed in Between trees after back filling

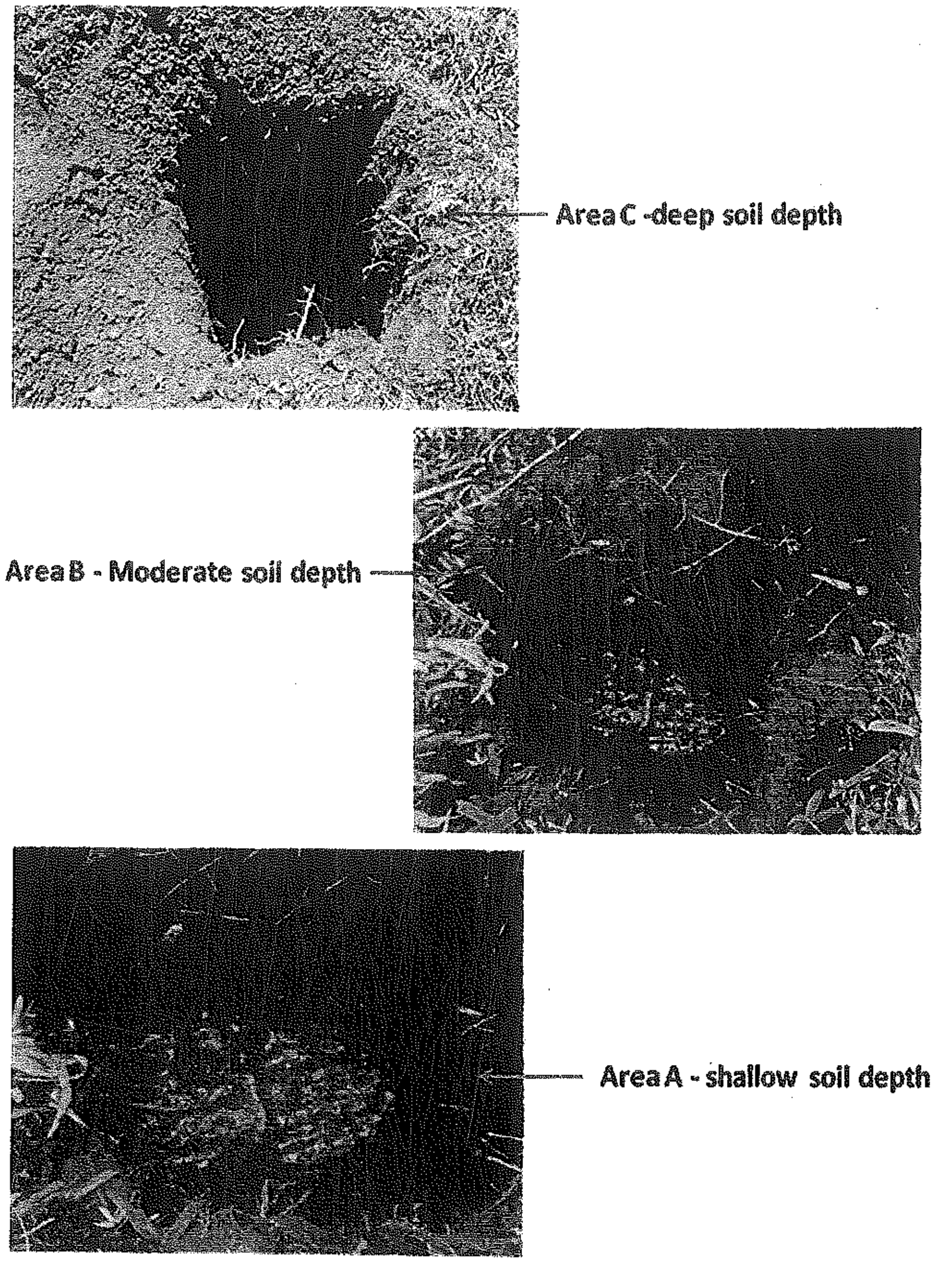

Plate 3: Soil depth of different mercury contaminated sites

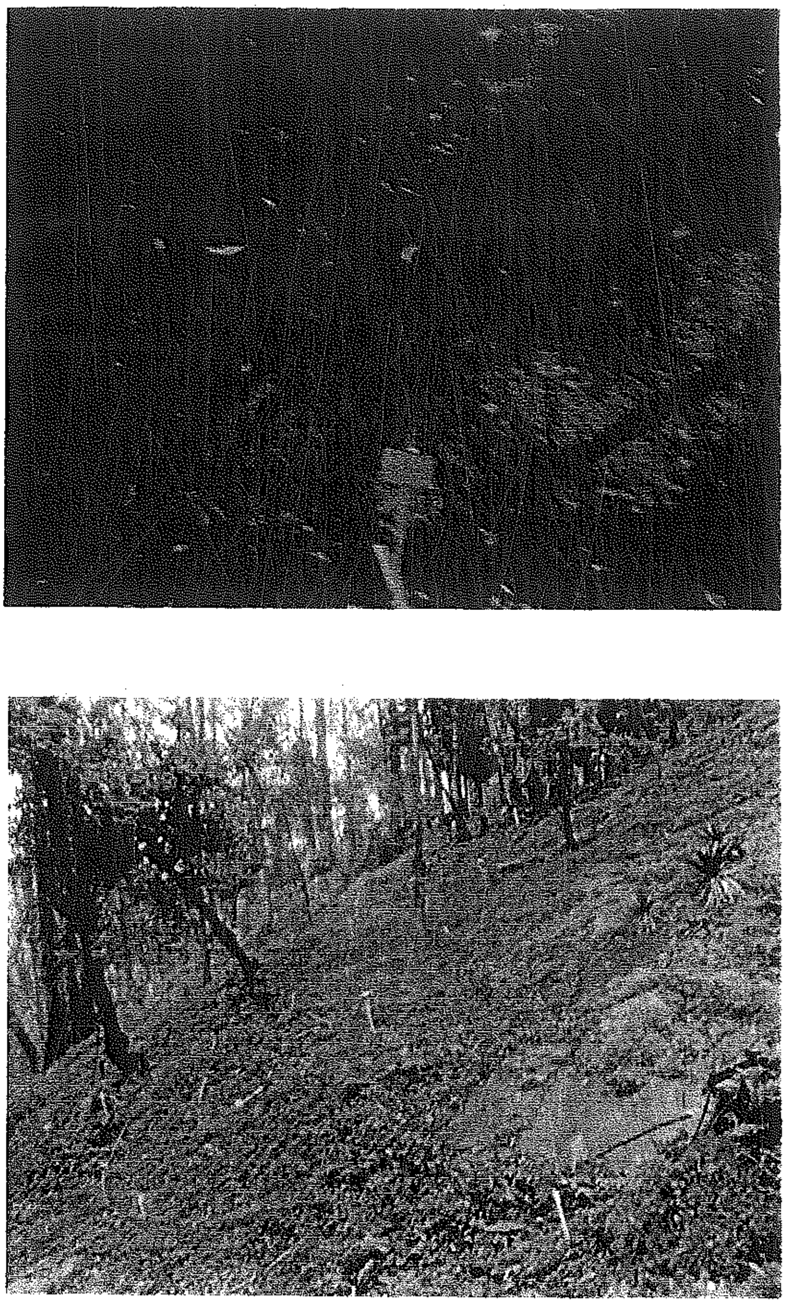

Plate 4: Steep slope area with rocky patches where excavation and backfilling is not possible in area A

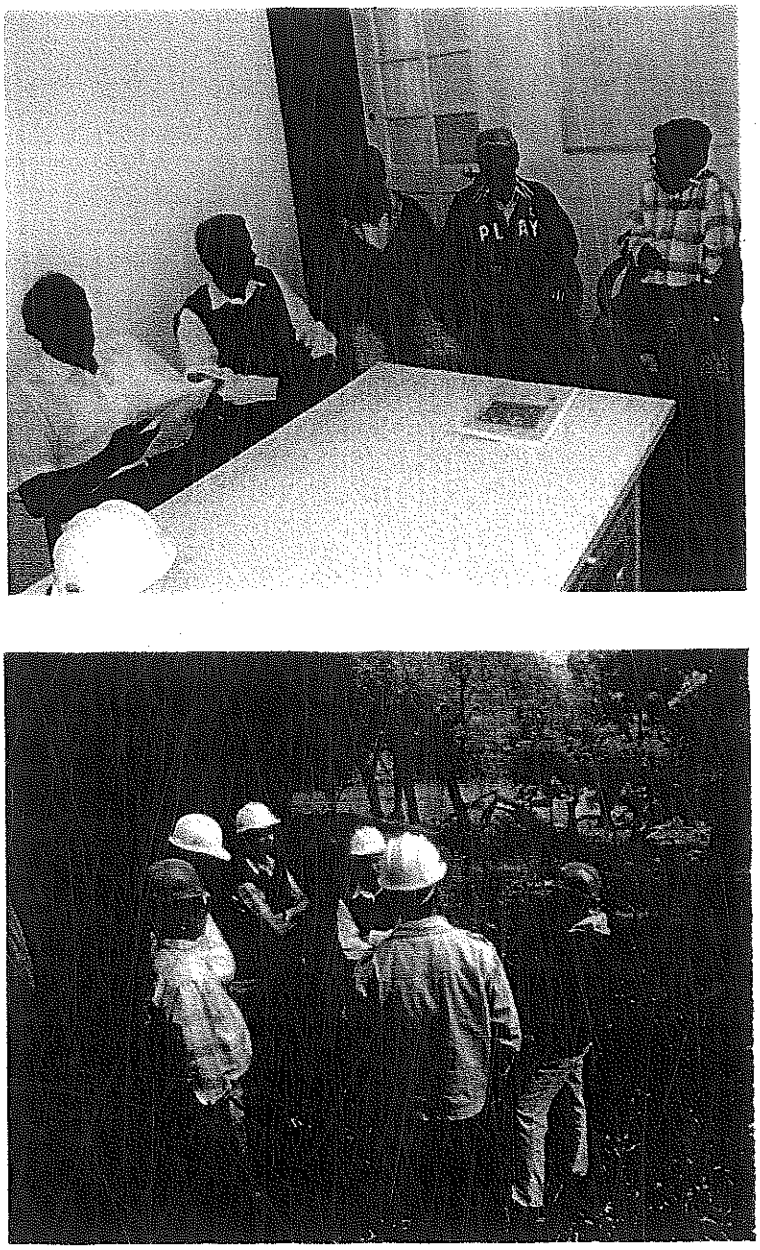

Plate 5: Interaction of consultants with HUL and ERM staffs