Capping of
Old Municipal Solid Waste Dumps
in India

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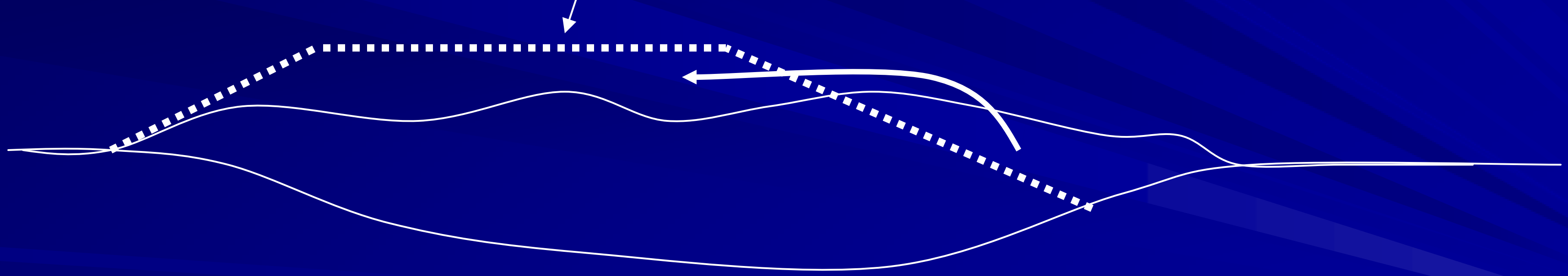
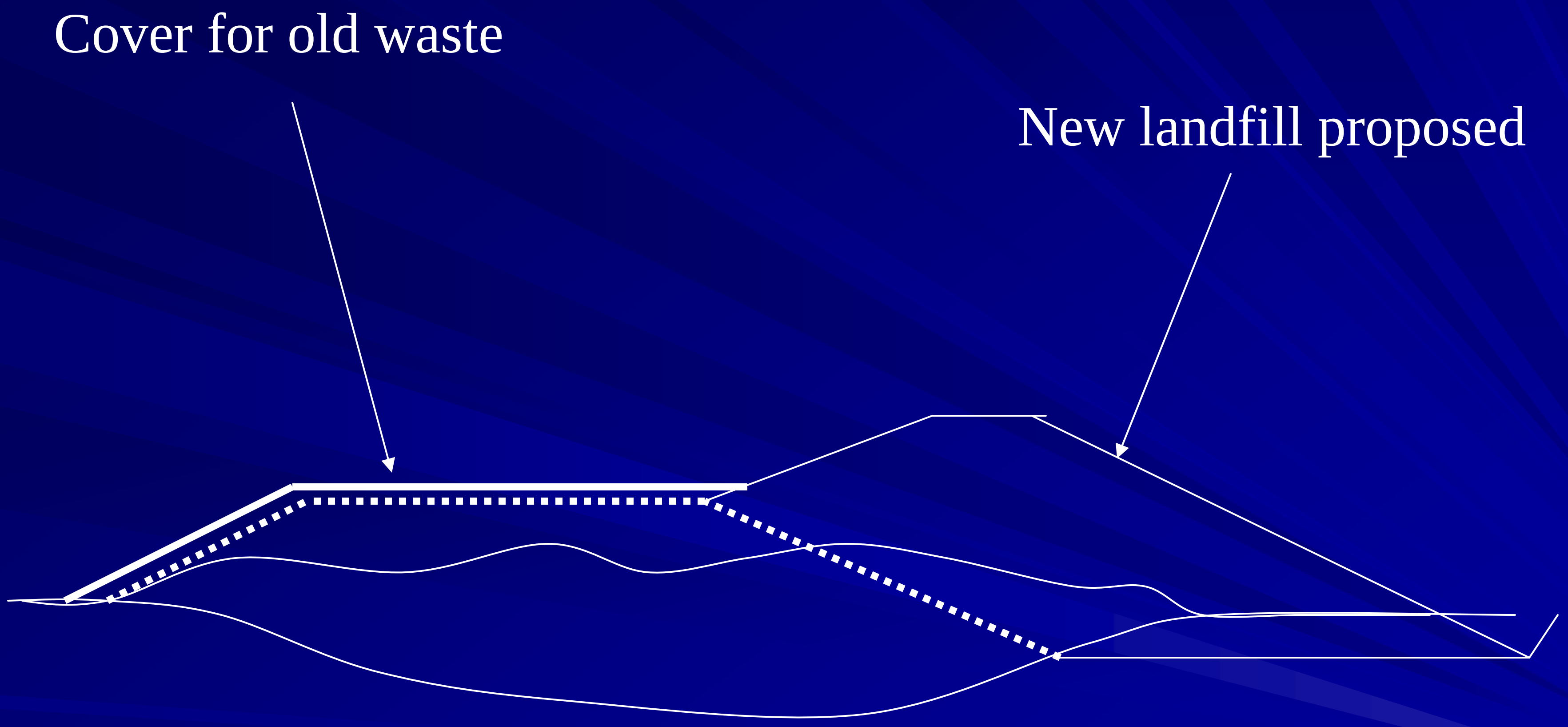
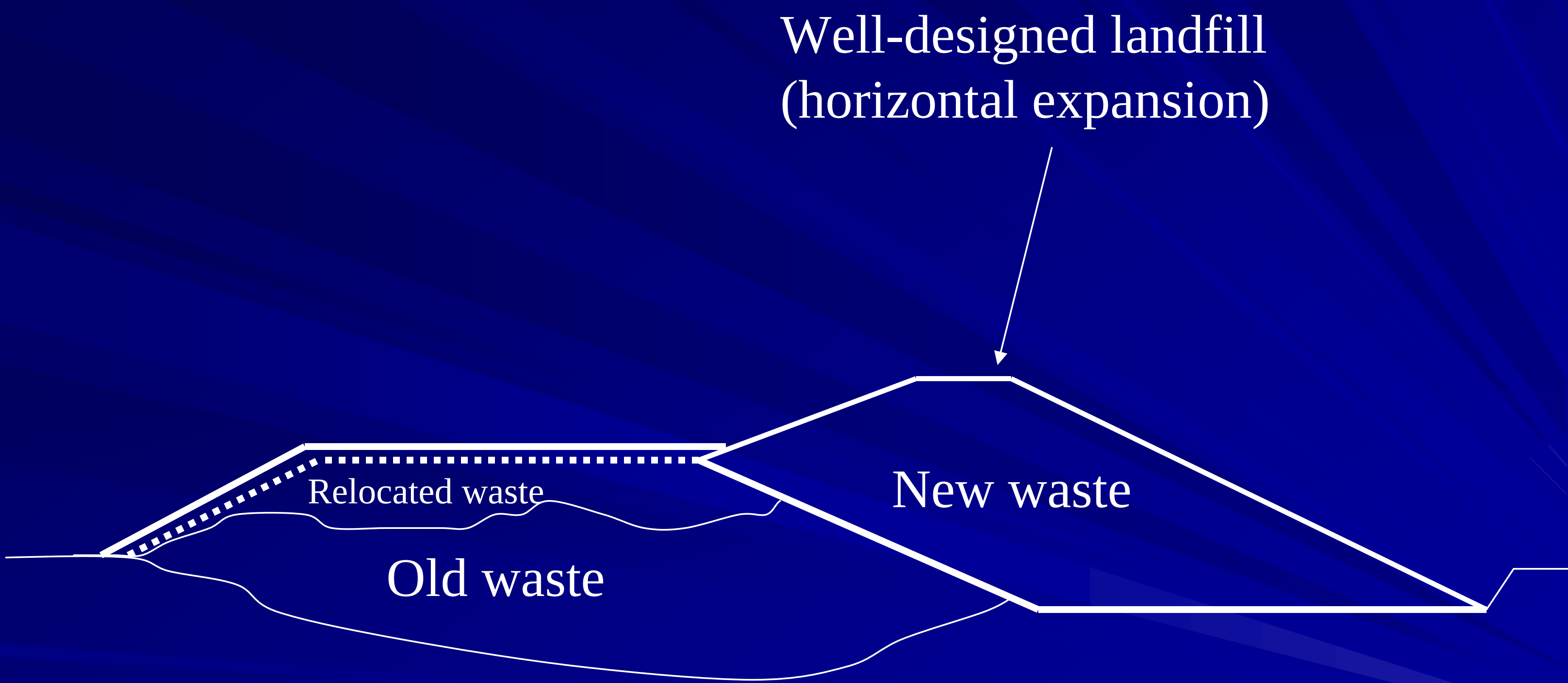
PEC University of Technology, Chandigarh

Closure and Horizontal Expansion

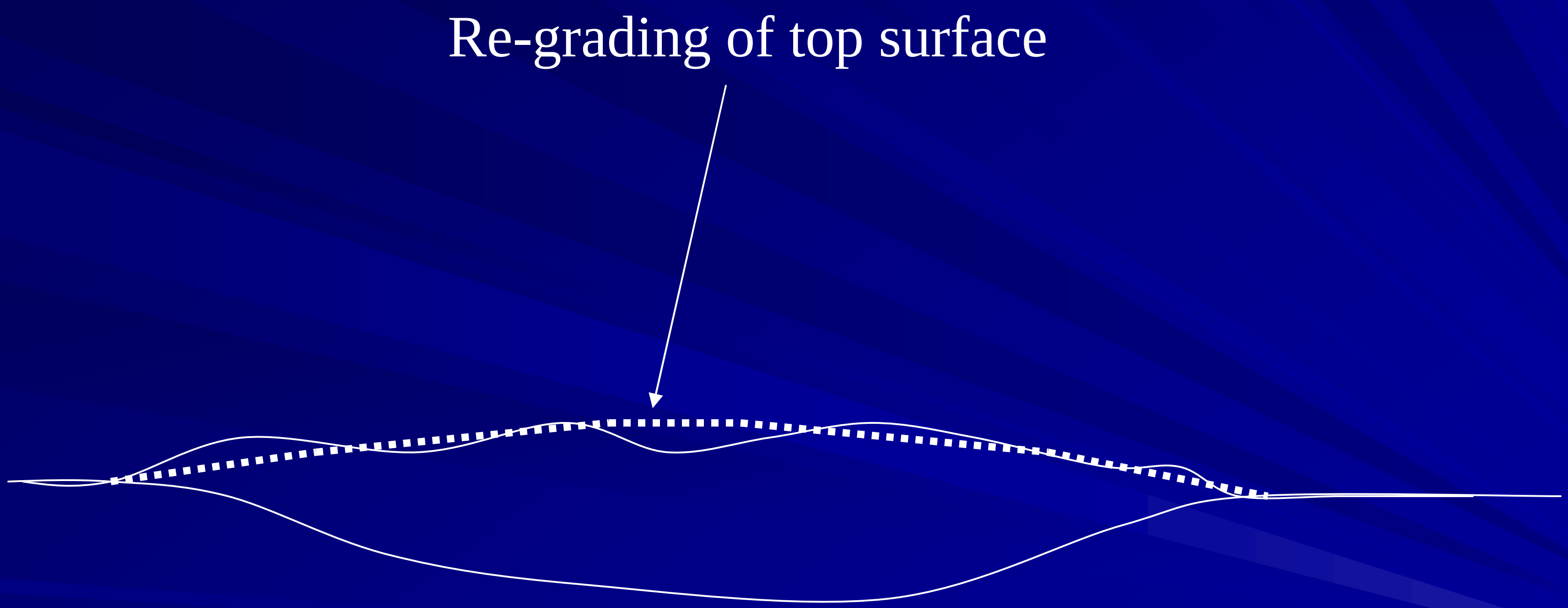
Relocation of waste and
re-grading of landfill



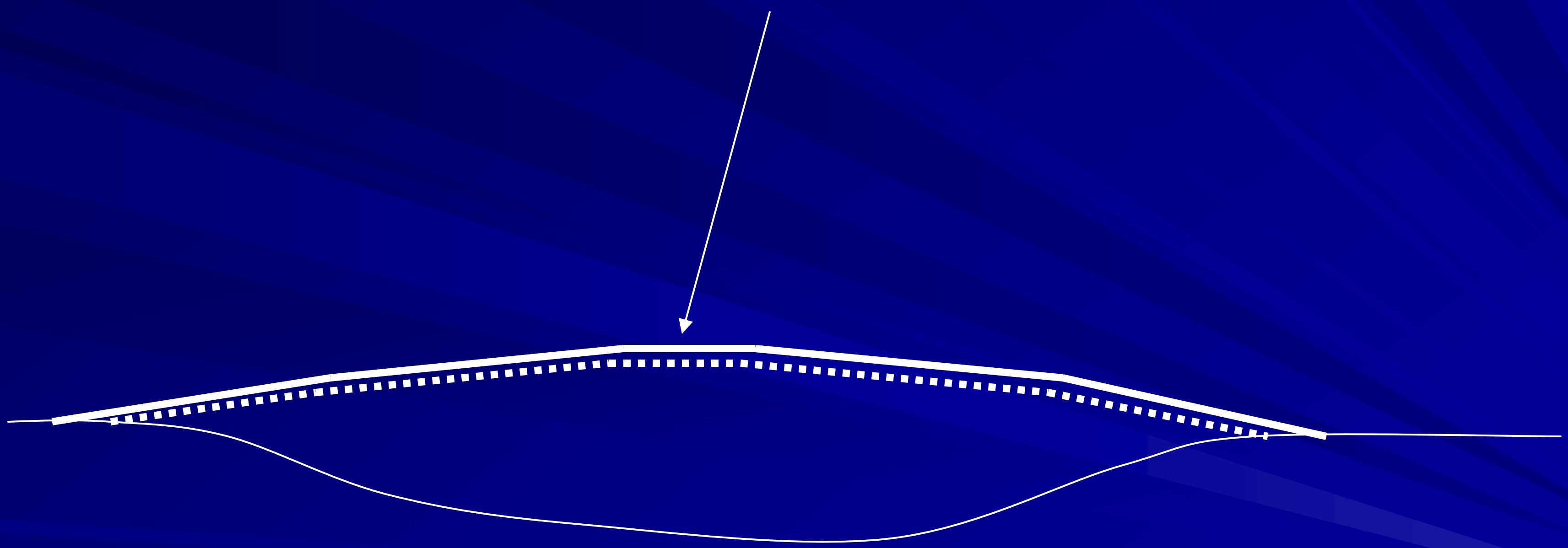

Cover for old waste
New landfill proposed

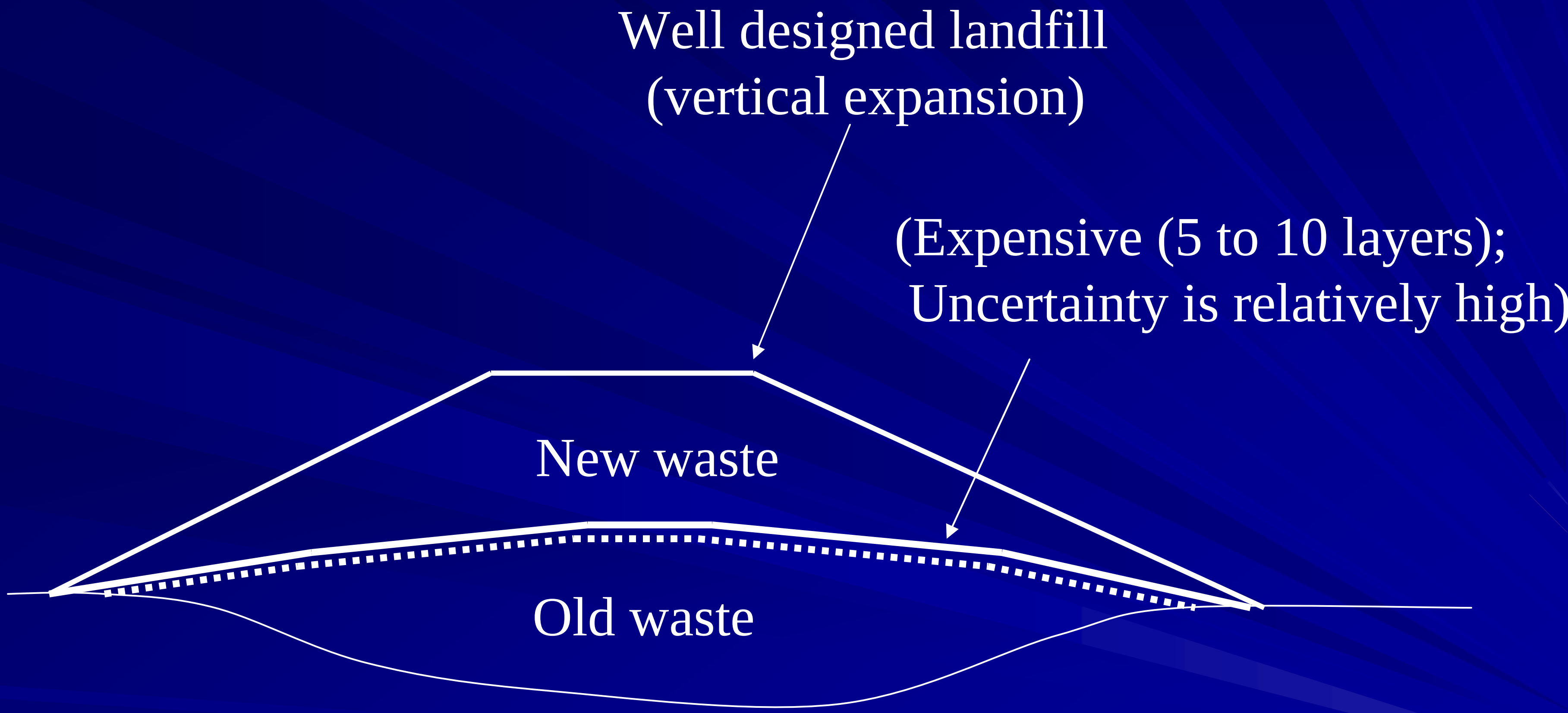

Well-designed landfill
(horizontal expansion)
Relocated waste
New waste
Old waste

Closure and Vertical Expansion


Re-grading of top surface

Cover for old waste and
liner for new waste




Well designed landfill
(vertical expansion)
(Expensive (5 to 10 layers);
Uncertainty is relatively high)
New waste
Old waste

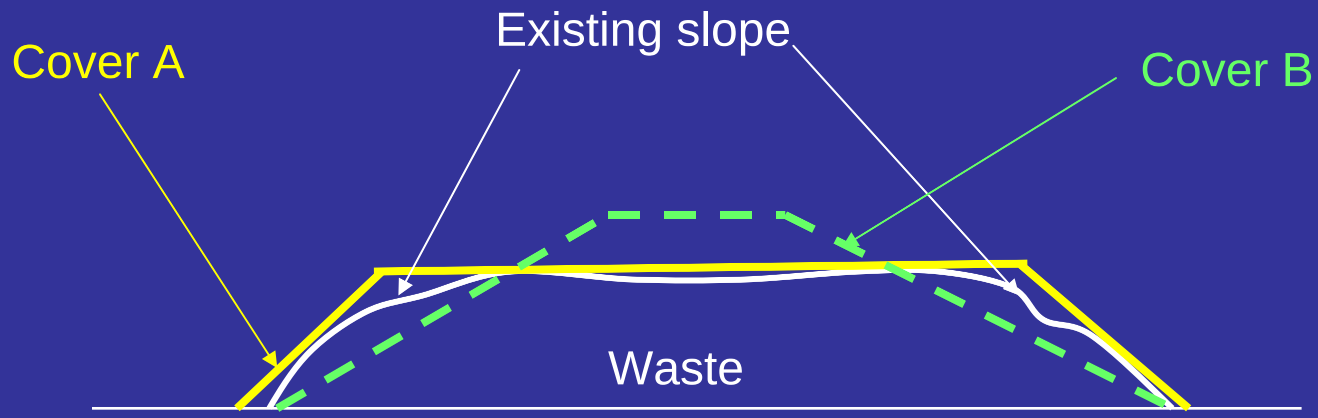
Okhla Waste Dump, Delhi

Ghazipur Waste Dump, Delhi

Gorai Waste Dump, Mumbai
(before capping)

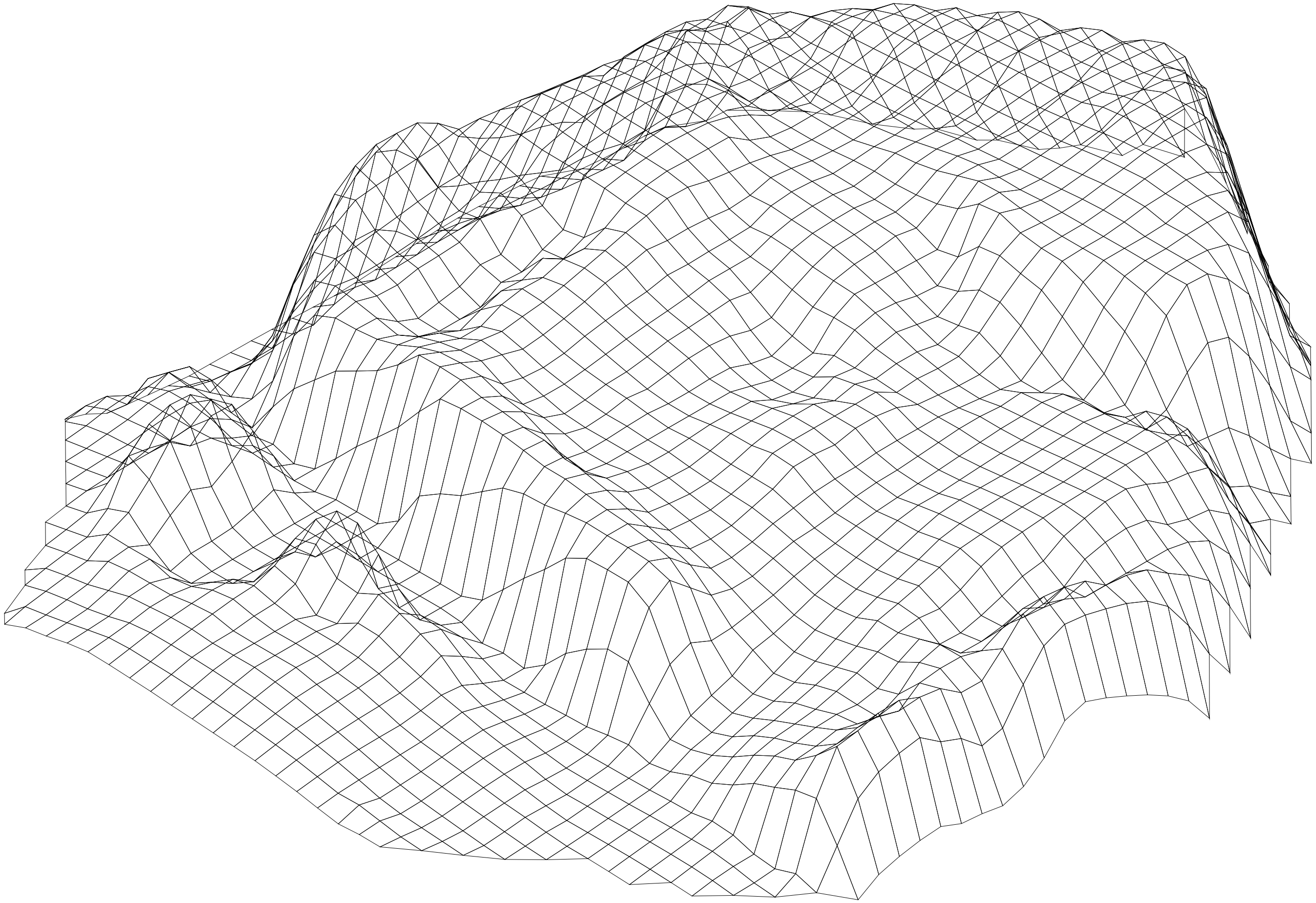
The Problem

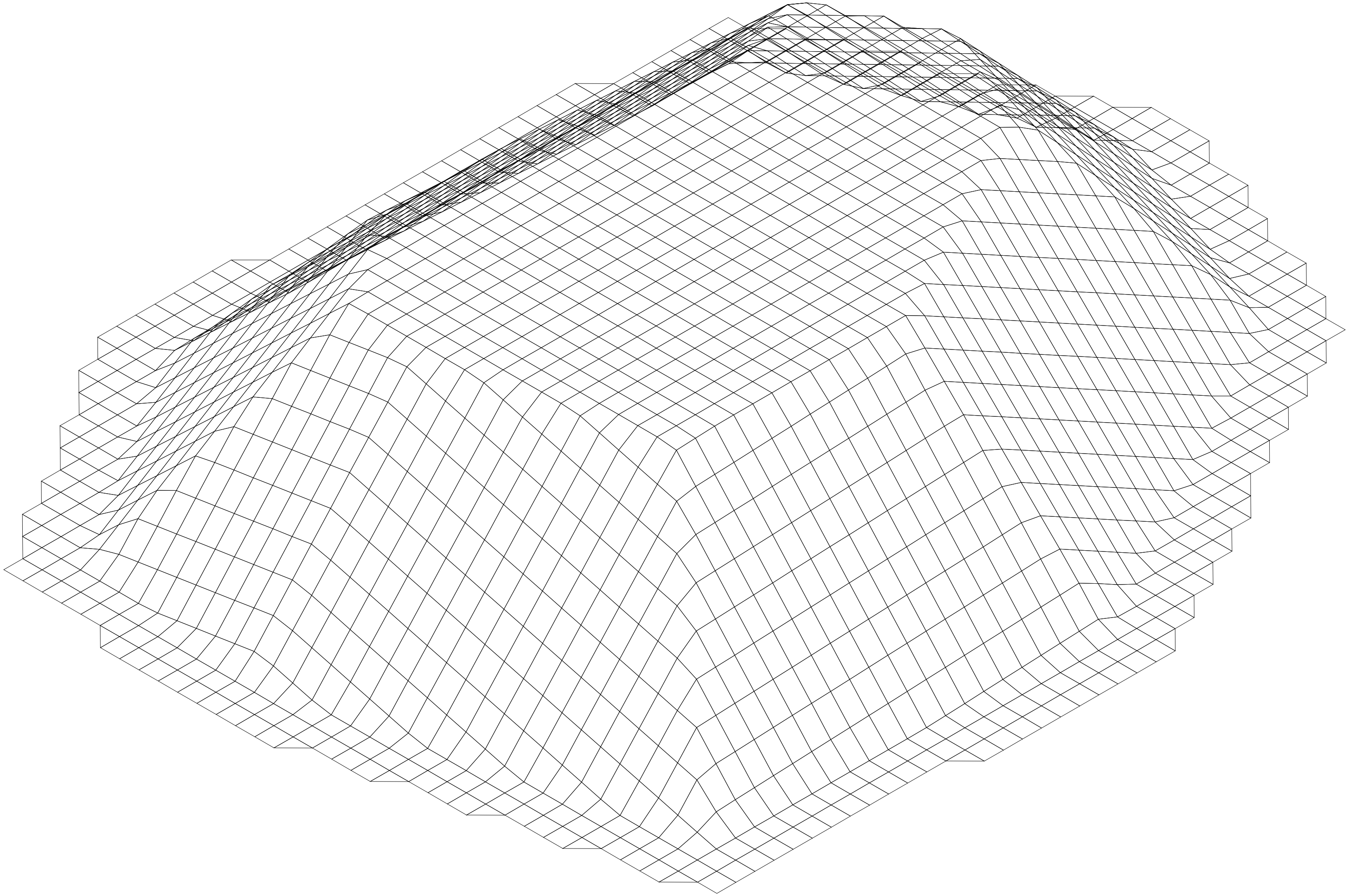
- To provide a cover system which is stable at the existing slope angle or at a steep slope angle such that re-location of the waste is minimum.



Gas Collection

- Old MSW dumps with heights greater than 15 meters emit significant quantities of methane
- Gas collection and flaring / utilization offers the possibility of earning carbon credits
- Use of geomembranes in covers improves gas collection efficiency
- Geomembranes can affect slope stability due to slippage along interfaces.





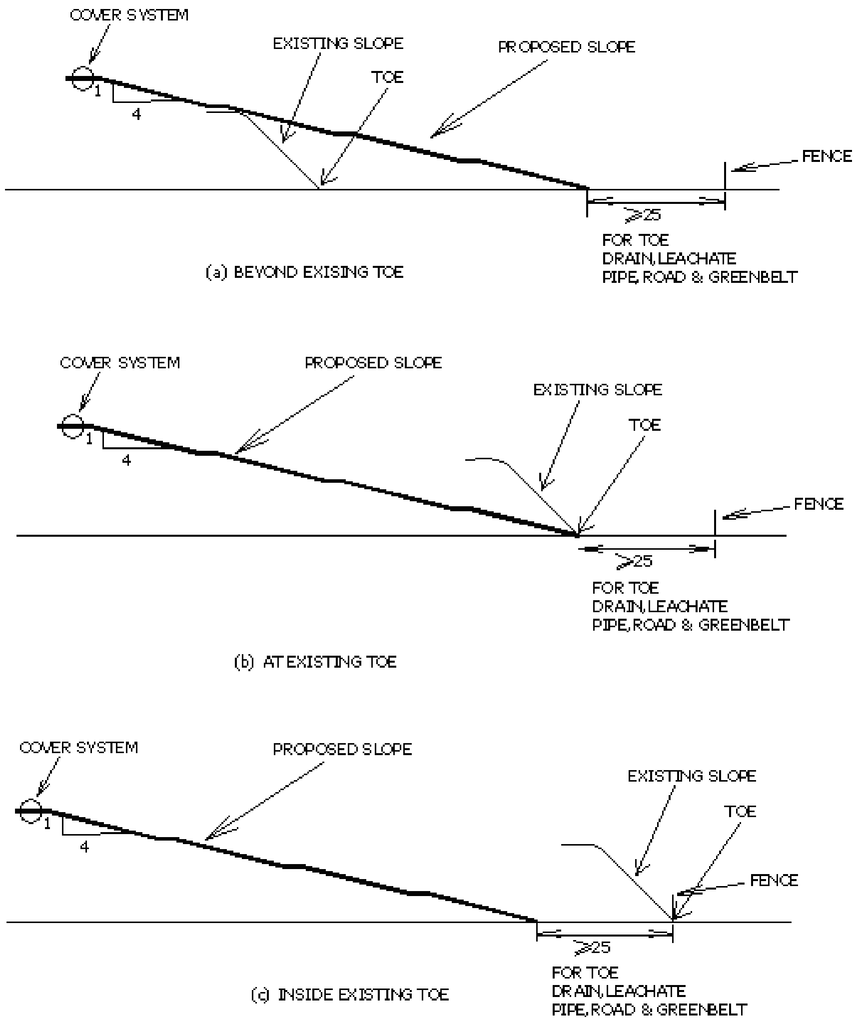
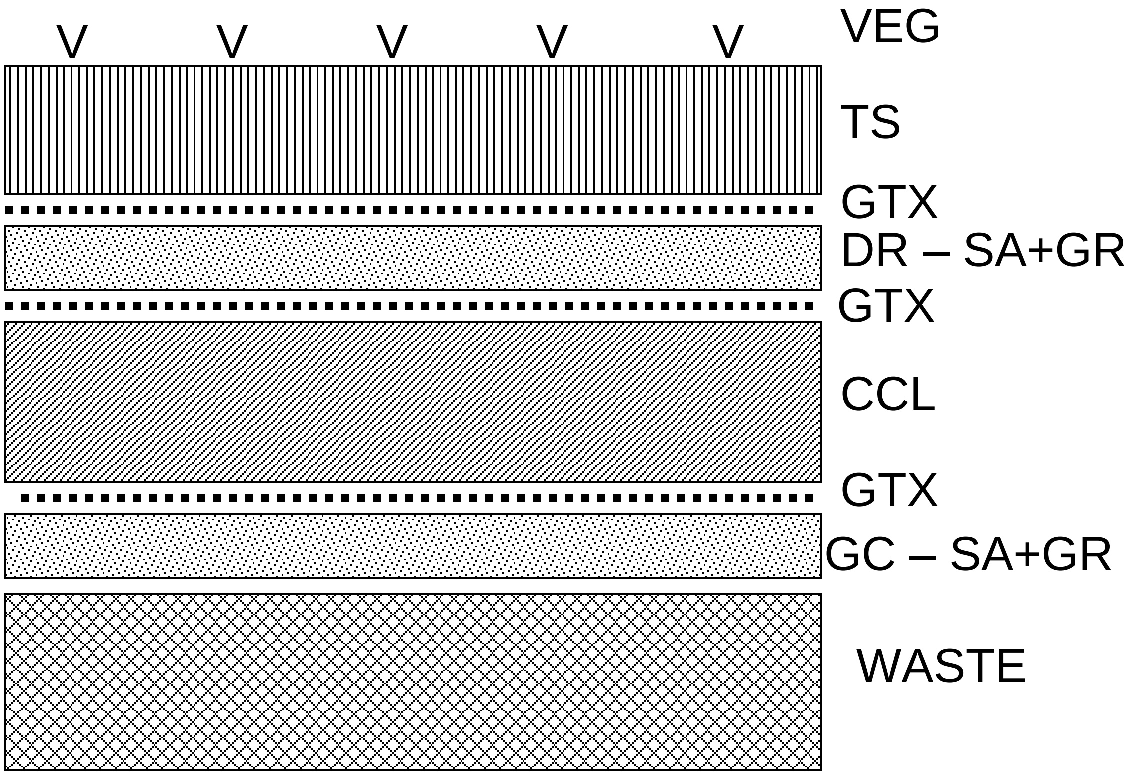
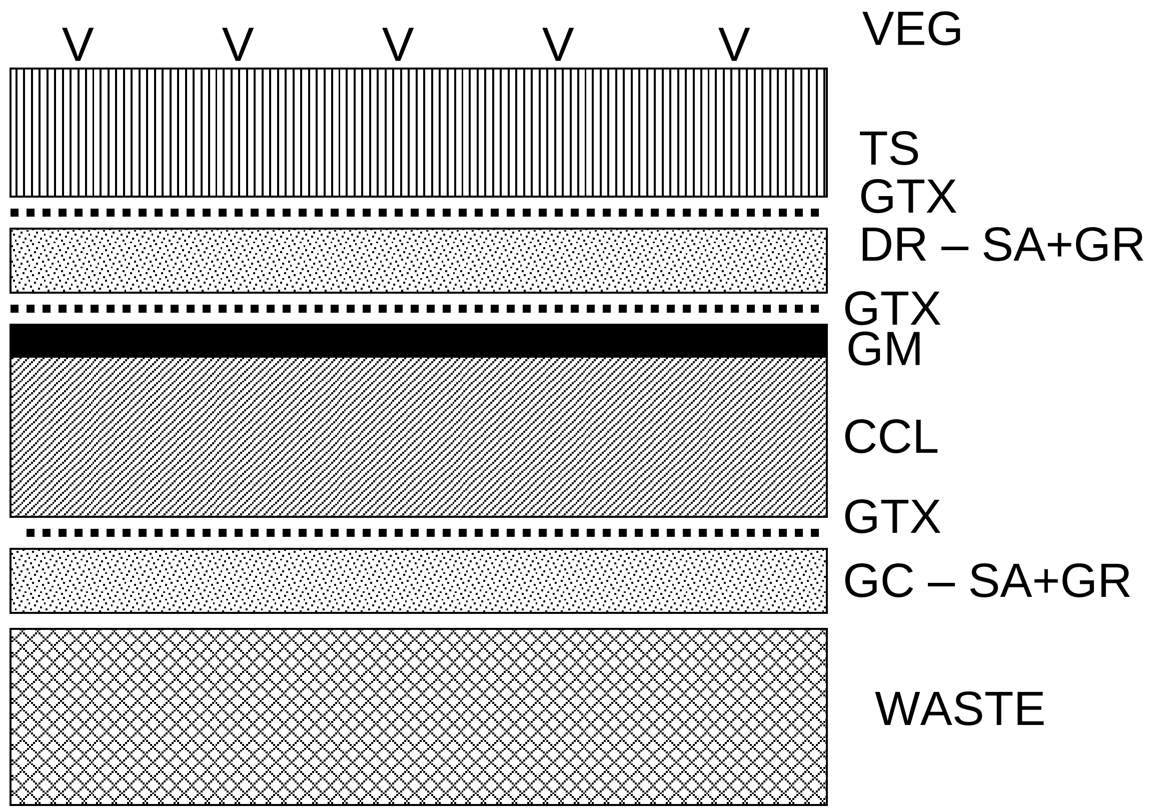


FIG 5:REGRADATION OF SLOPE



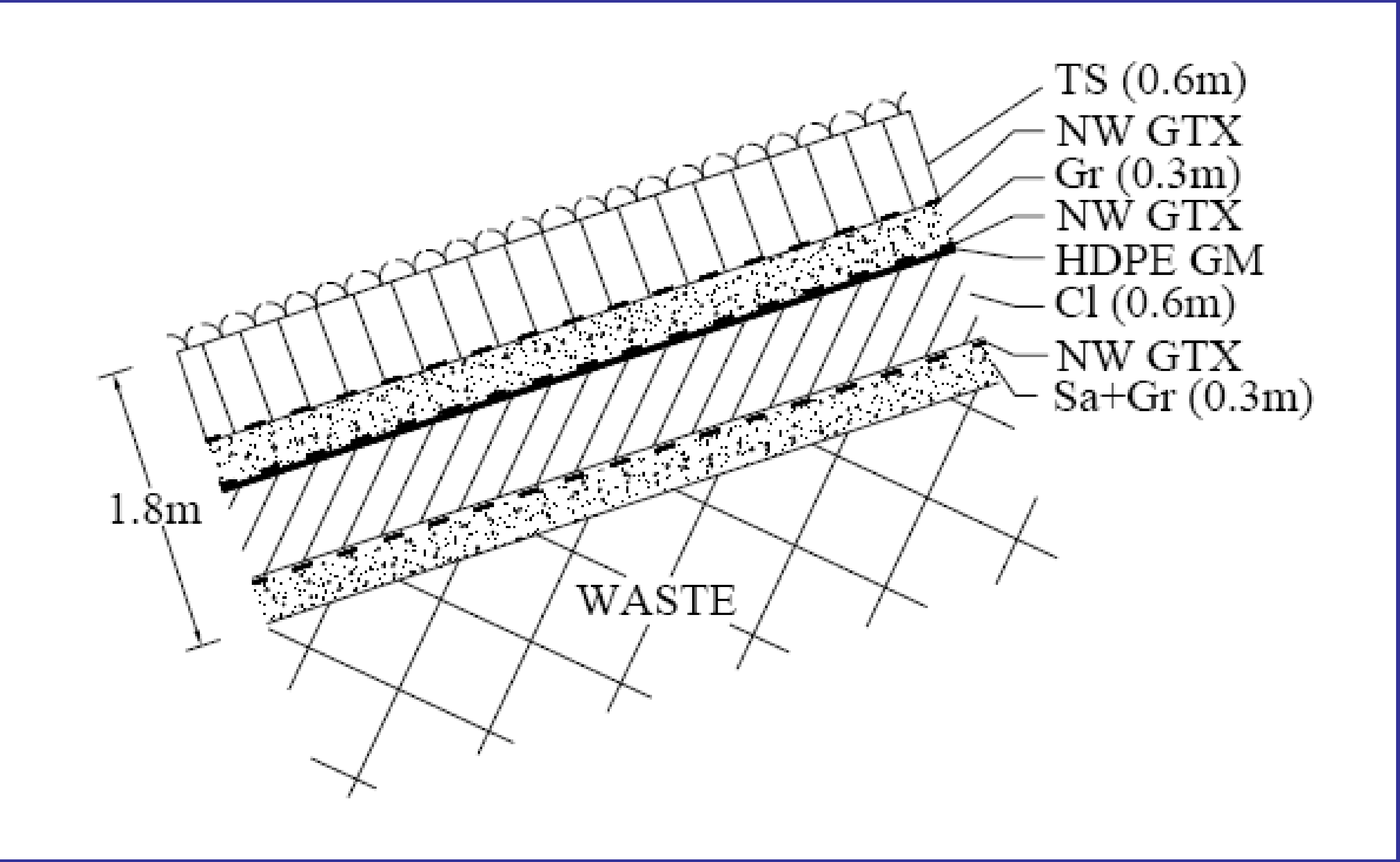
Cover for MSW



Cover for HW

or

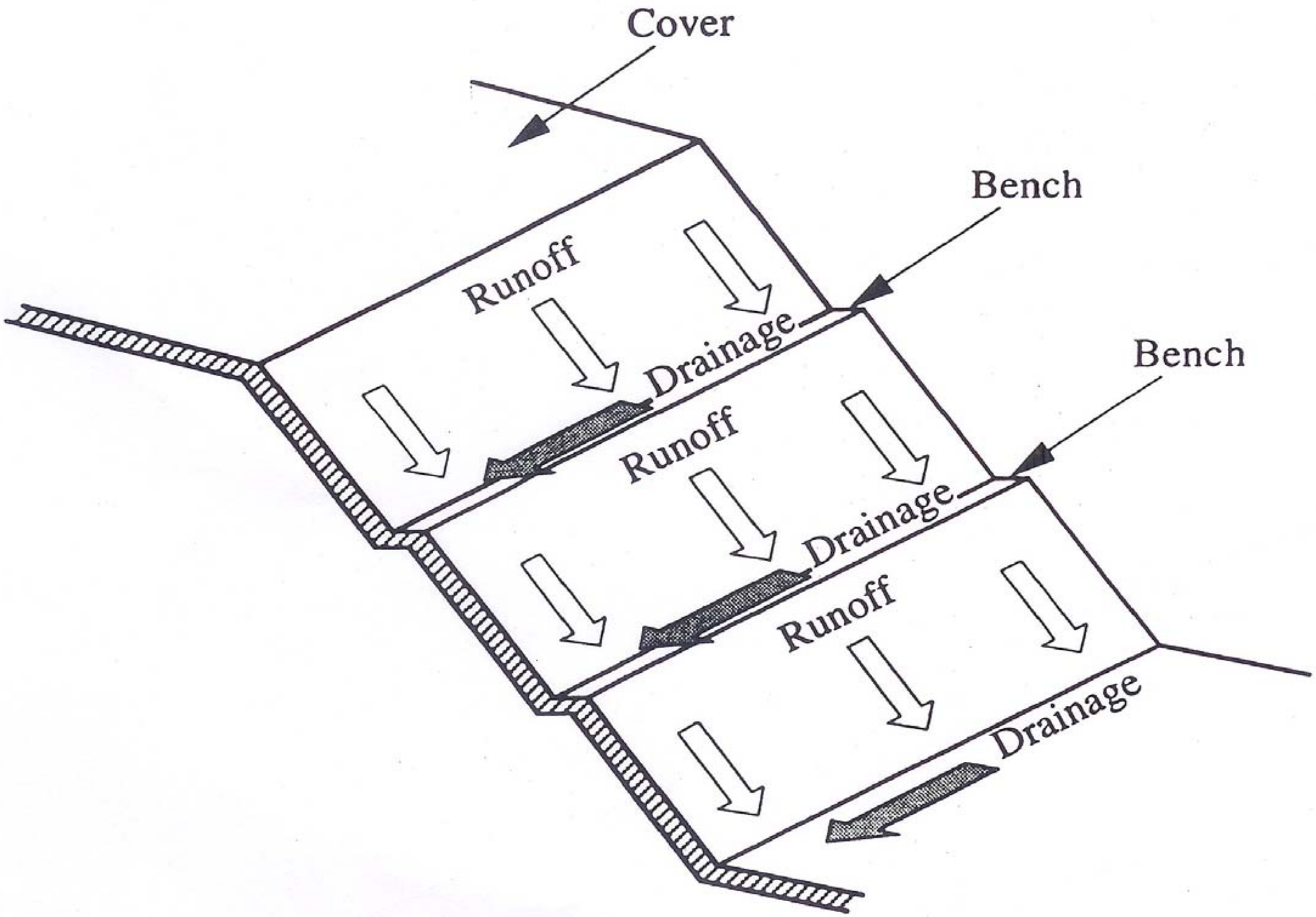
Cover for MSW (with Gas Recovery (high efficiency))


TS (0.6m)
NW GTX
Gr (0.3m)
NW GTX
HDPE GM
Cl (0.6m)
NW GTX
Sa+Gr (0.3m)
1.8m
WASTE

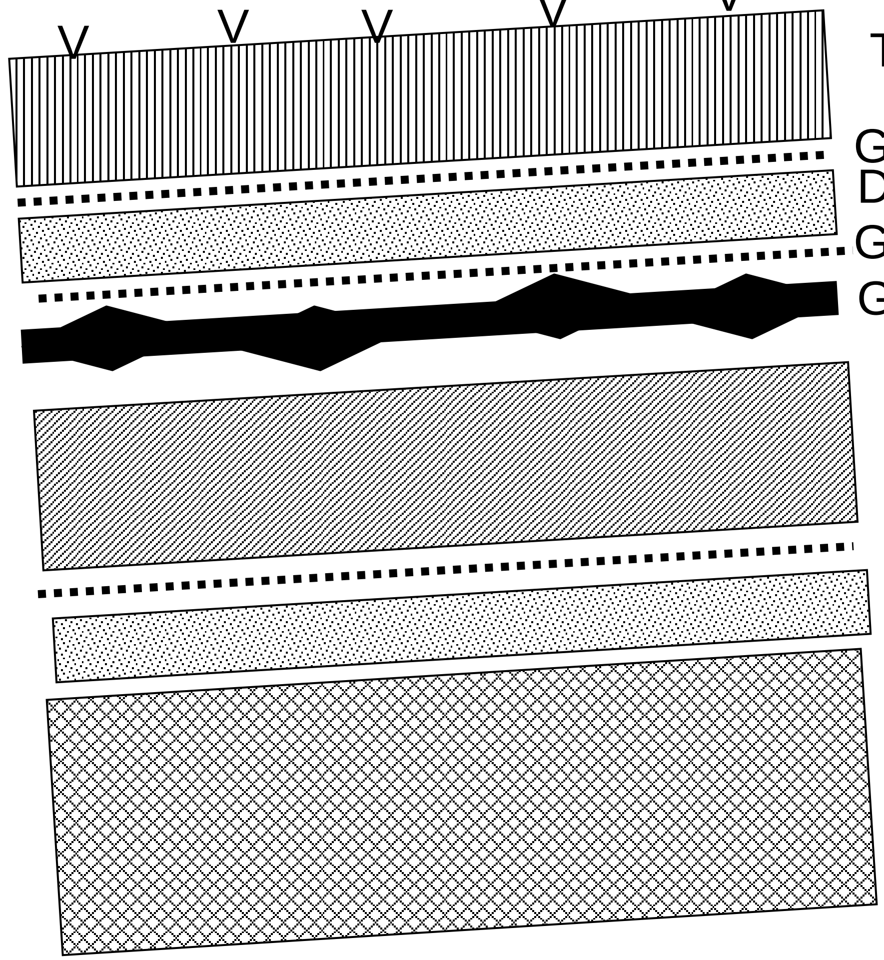
Cover A

Acceptable Factors of Safety for Slope Stability

	Condition	Acceptable factor of safety
1	Static case (long term)	1.5
2	Seepage flow during monsoon (short duration)	1.3
3	Earthquake loading (very short duration)	1.1
4	Earthquake loading + Seepage flow (rare)	1.0



Isometric Sketch of Possible Runoff Pattern from Benched Constant Slope Angle Final Cover



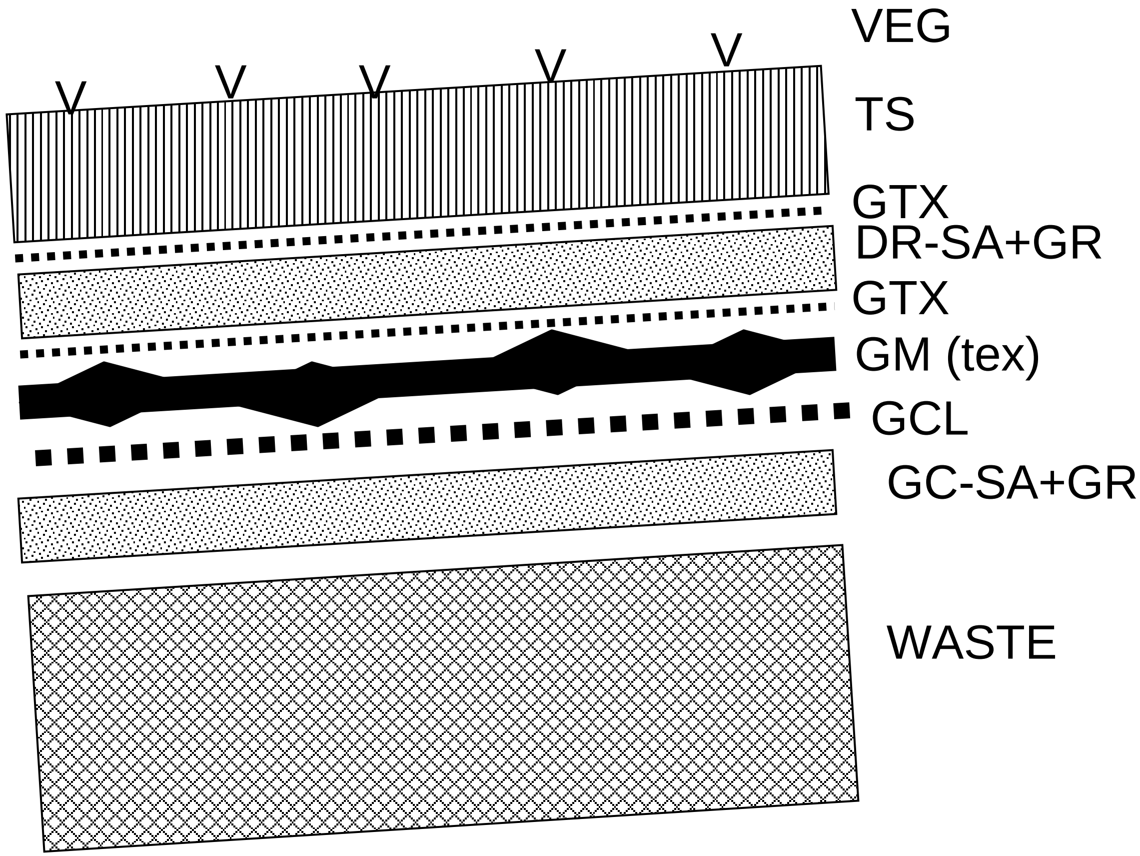
Cover System A with Textured Geomembrane

Table 1 : Interface Shear Strength Parameters

Base Material	Underlying/Overlying Material	Peak Parameters		Residual Parameters	
		C_a(kPa)	δ (deg)	C_a(kPa)	δ (deg)
Smooth HDPE Geomembrane	Saturated clay	0	11	0	9
Textured HDPE geomembrane	Saturated clay	0	18	0	14
Smooth, HDPE Geomembrane	Non woven, needle punched Geotextile	0	11	0	9
Textured HDPE Geomembrane	Non woven, needle punched Geotextile	0	22	0	17
Textured HDPE geomembrane	Saturated sand	0	34	0	31
Textured HDPE Geomembrane	Geocomposite drain: geonet + non woven needle punched geotextile on both sides	0	24	0	17
Nonwoven needlepunched geotextile	Saturated sand	0	32	0	32
Textured HDPE Geomembrane	Non woven, needle punched geosynthetic clay liner	0	32	0	20

Table 2. Factor of Safety for GM (textured) – Clay Interface (δ=14°) for Cover A

Slope angle	Height (between berms) (m)	Factor of safety
3 : 1 (18.4°)	10	0.86
	5	0.98
4 : 1 (14.0°)	10	1.11
	5	1.23
5 : 1 (11.3°)	10	1.36
	5	1.48



Cover System B with Textured Geomembrane (CCL replaced by GCL)

Table 1 : Interface Shear Strength Parameters

Base Material	Underlying/Overlying Material	Peak Parameters		Residual Parameters	
		C_a(kPa)	δ (deg)	C_a(kPa)	δ (deg)
Smooth HDPE Geomembrane	Saturated clay	0	11	0	9
Textured HDPE geomembrane	Saturated clay	0	18	0	14
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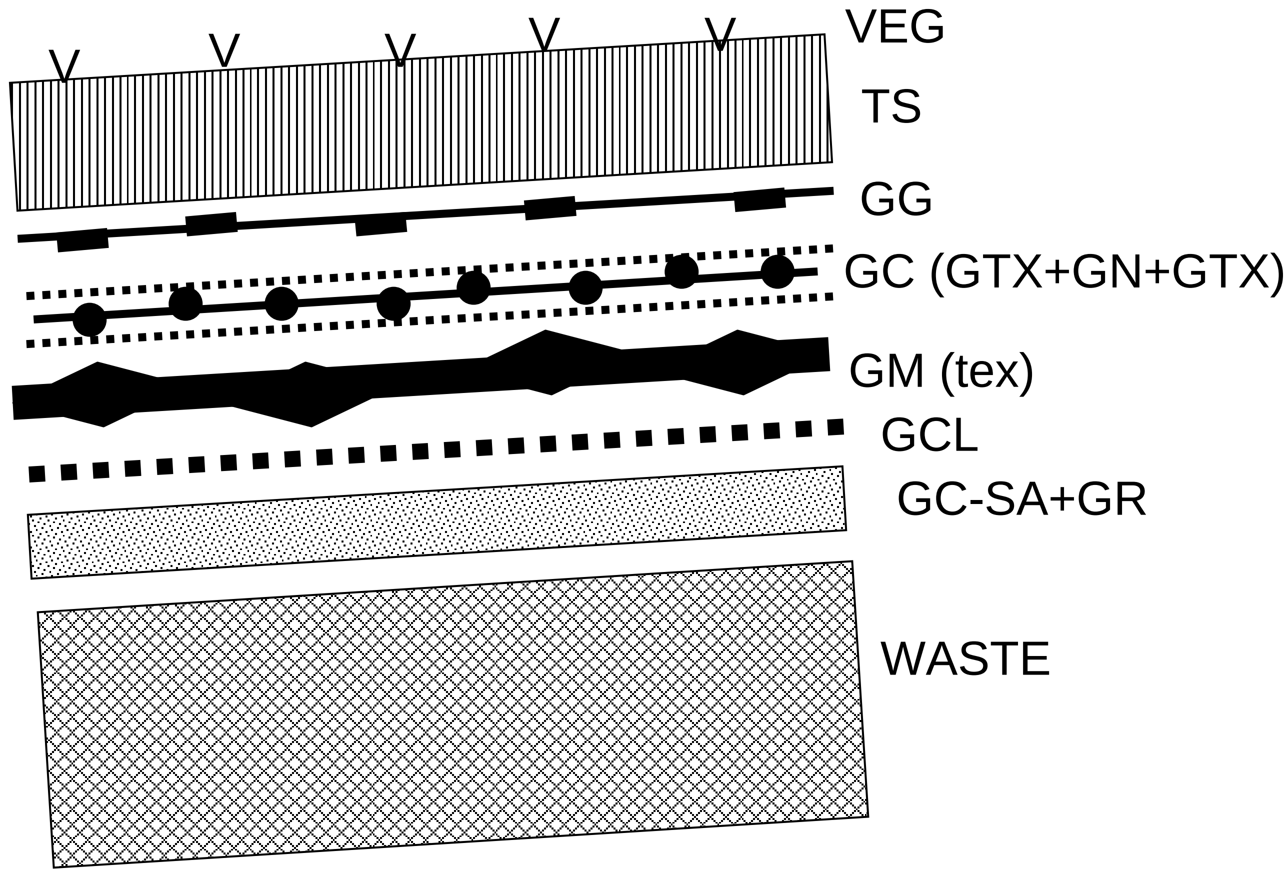
Textured HDPE Geomembrane	Non woven, needle punched Geotextile	0	22	0	17
Textured HDPE geomembrane	Saturated sand	0	34	0	31
Textured HDPE Geomembrane	Geocomposite drain: geonet + non woven needle punched geotextile on both sides	0	24	0	17
Nonwoven needlepunched geotextile	Saturated sand	0	32	0	32
Textured HDPE Geomembrane	Non woven, needle punched geosynthetic clay liner	0	32	0	20



Cover System B with Textured Geomembrane and Geogrid Reinforcement and Geocomposite Drainage Layer

Table 7: Results of Stability Analysis at Interface of GM (textured) – Geotextile (NW, NP) (δ=17°) with Geogrid Reinforcement after replacing Drainage Layer by Geocomposite Drain (5mm)

Slope (H:V)	Height between Berm (m)	FOS With Reinforcement							
		Long Term Tensile strength T = 30 kN/m				Long Term Tensile strength T = 40 kN/m			
		Dry	Seepage	E.Q	E.Q + Seepage	Dry	Seepage	E.Q	E.Q + Seepage
2 : 1	5.00	2.24	1.63	1.23	1.01	19.64	6.53	2.51	1.98
	7.50	1.19	0.93	0.81	0.68	1.73	1.31	1.05	0.87
	10.00	0.96	0.77	0.69	0.58	1.19	0.93	0.81	0.68
2.5 : 1	5.00	2.80	2.04	1.40	1.17	24.47	8.15	2.61	2.13
	7.50	1.48	1.17	0.96	0.81	2.16	1.63	1.21	1.02
	10.00	1.20	0.96	0.83	0.70	1.48	1.17	0.96	0.81
3 : 1	5.00	3.36	2.45	1.55	1.31	29.55	9.80	2.68	2.25
	7.50	1.78	1.40	1.09	0.93	2.59	1.96	1.36	1.15
	10.00	1.44	1.15	0.95	0.81	1.78	1.40	1.09	0.93
3.5:1	5.00	3.92	2.86	1.67	1.43	34.56	11.45	2.73	2.34
	7.50	2.08	1.63	1.20	1.03	3.02	2.29	1.48	1.27
	10.00	1.68	1.34	1.05	0.91	2.08	1.63	1.20	1.03
4:1	5.00	4.47	3.26	1.77	1.54	39.11	13.03	2.76	2.41
	7.50	2.37	1.86	1.30	1.13	3.45	2.61	1.58	1.37
	10.00	1.92	1.54	1.15	1.00	2.37	1.86	1.30	1.13

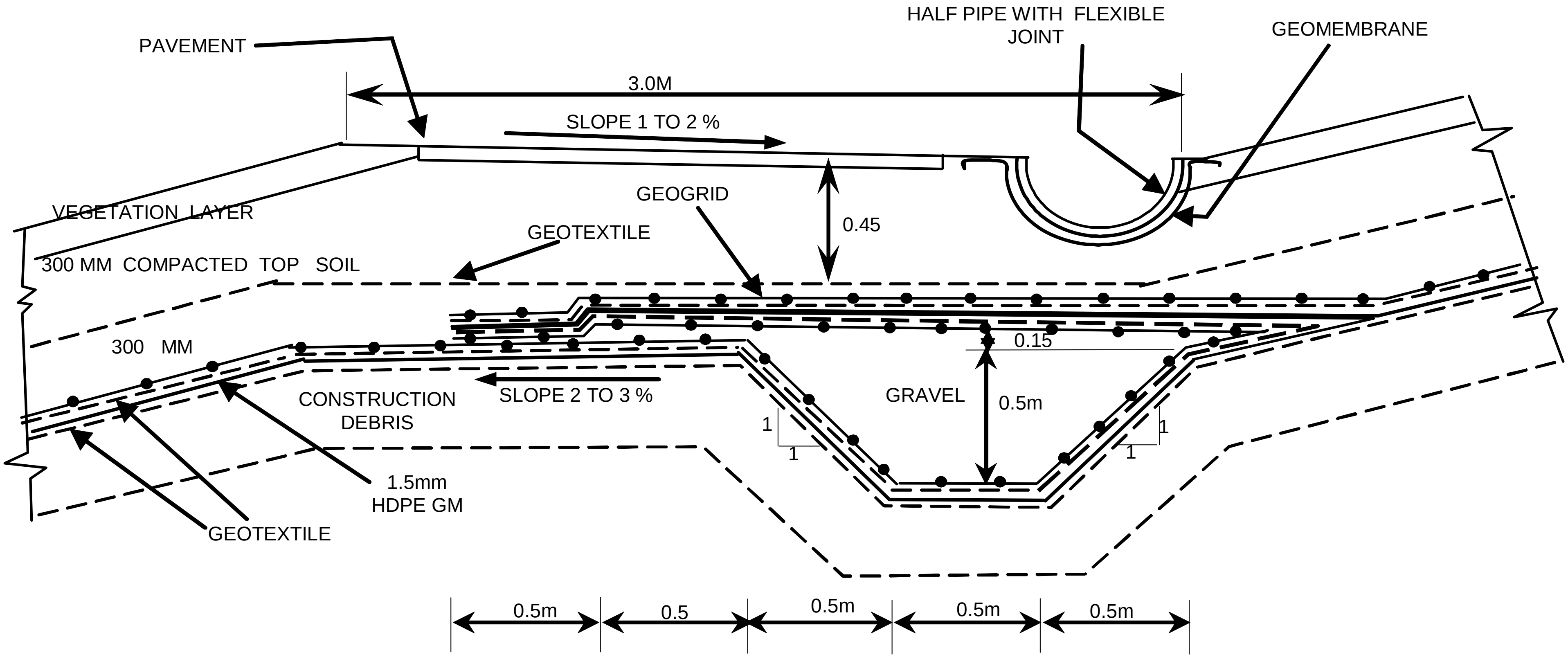
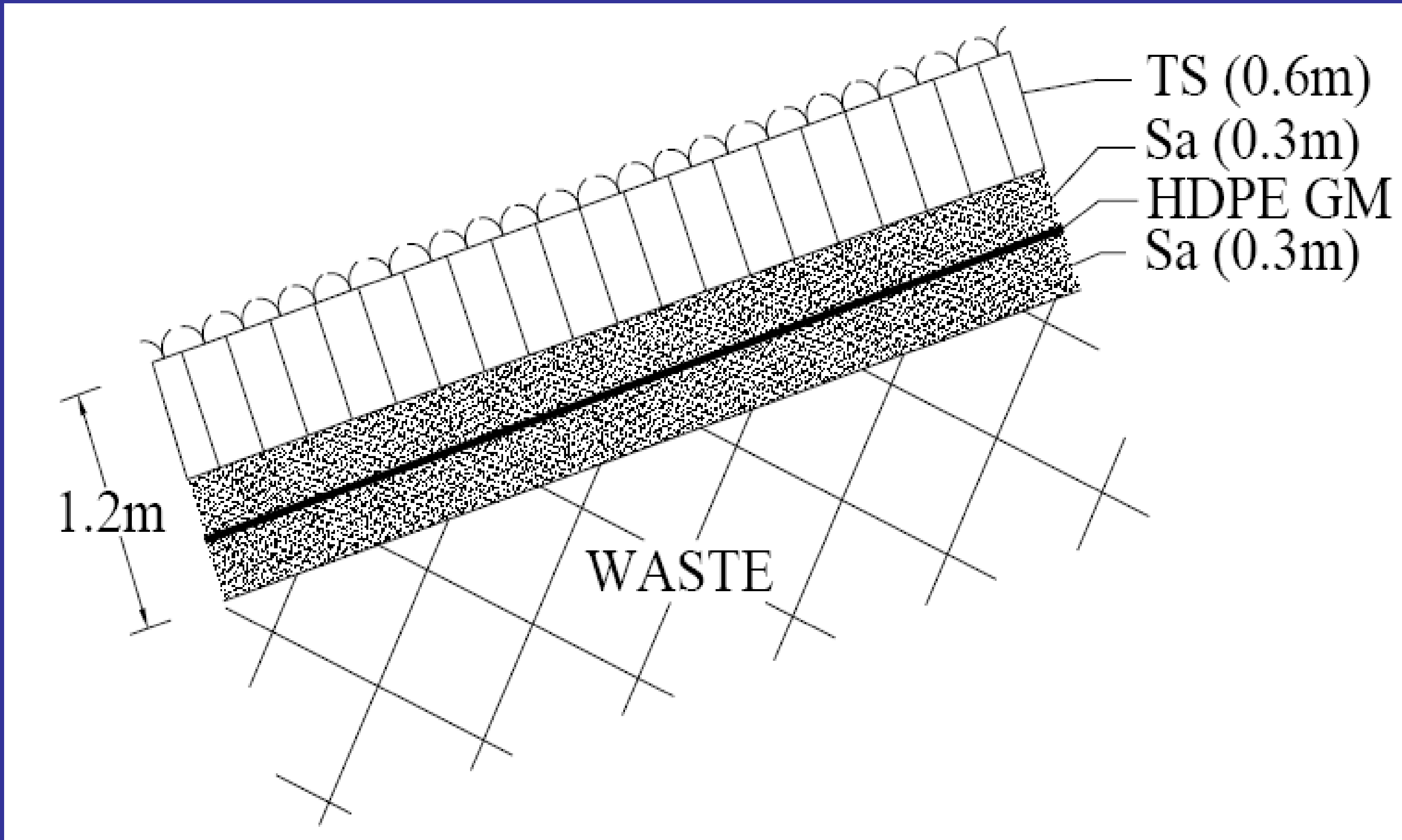
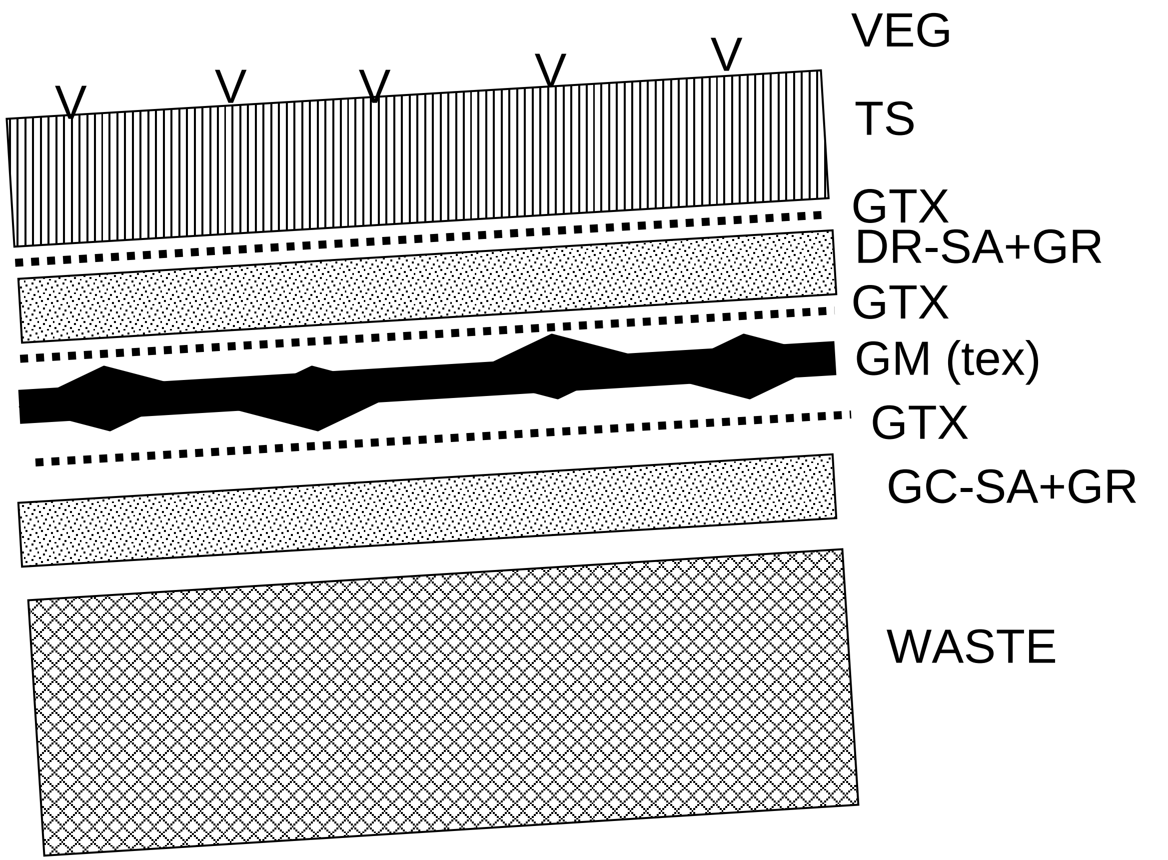


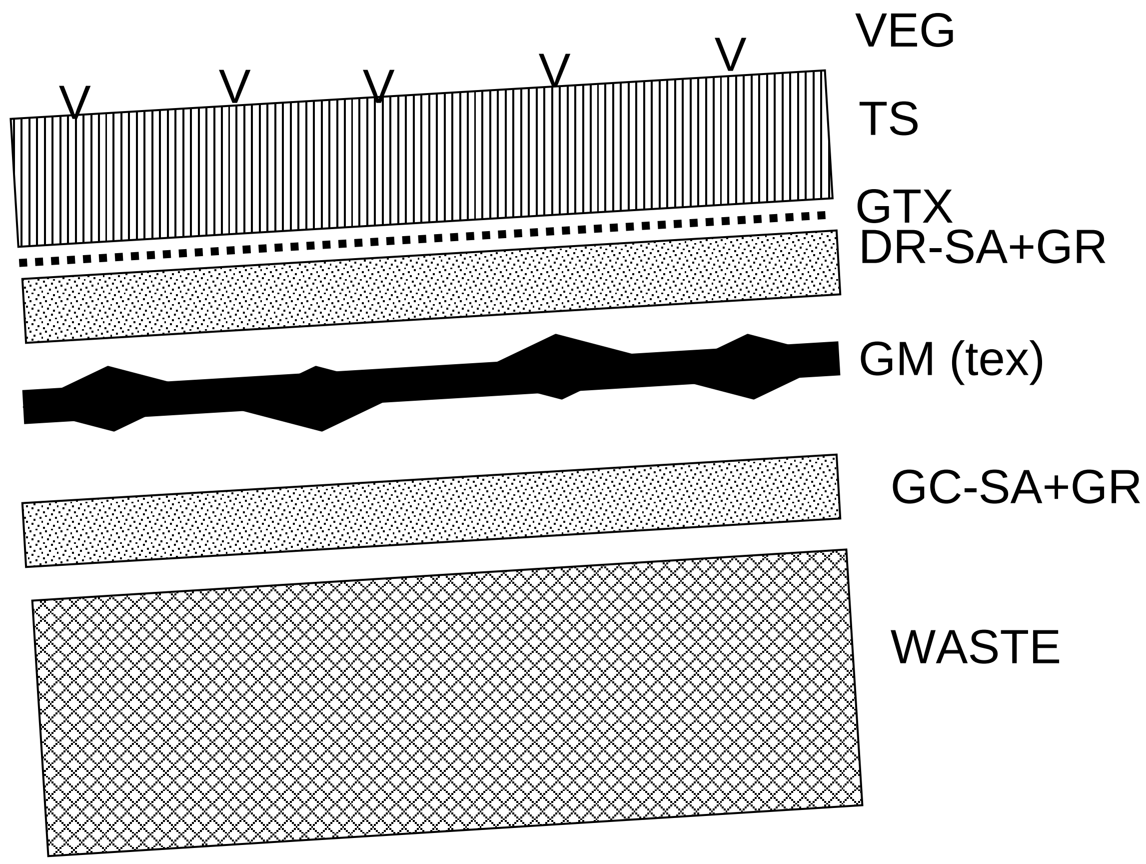
Fig. 12 Wrap – Around Anchor Trench



Cover C



Cover System C with Textured Geomembrane



Cover System D with Textured Geomembrane

Table 1 : Interface Shear Strength Parameters

Base Material	Underlying/Overlying Material	Peak Parameters		Residual Parameters	
		C_a(kPa)	δ (deg)	C_a(kPa)	δ (deg)
Smooth HDPE Geomembrane	Saturated clay	0	11	0	9
Textured HDPE geomembrane	Saturated clay	0	18	0	14
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Textured HDPE geomembrane	Saturated sand	0	34	0	31
Textured HDPE Geomembrane	Geocomposite drain: geonet + non woven needle punched geotextile on both sides	0	24	0	17
Nonwoven needlepunched geotextile	Saturated sand	0	32	0	32
Textured HDPE Geomembrane	Non woven, needle punched geosynthetic clay liner	0	32	0	20

Table 8 : Results of Stability Analysis at Interface of GM (textured) – Sand (δ= 31) for Cover D

Slope (H:V)	Dry	Seepage	E.Q.	E.Q. + Seepage
2 : 1	1.20	1.04	0.95	0.84
2.5 : 1	1.50	1.30	1.15	1.00
3 : 1	1.81	1.58	1.33	1.19

GORAI PROJECT

- Location: Borivali, Mumbai
- Total land area: 22 hectares
- Foot print area for closure: 19 hectares
- Total quantity of waste: 15 Million Tones
- Project duration: 18 Months
- Side Slope: 1V:3.5H
- Height of the Dump: 32 m
- Cost of project: Rs.62 crores including post closure maintenance of 15 years

Laying of Cover System : Sloping Area

Receiving, Relocating, Leveling, Reformation and Dressing of Existing MSW

Action Plan for Fire Control

- A separate team of 6 persons under the Project Manager is formed who are responsible for reporting & control of fire.
- This team are given separate machineries – Poclains, Dozer, Water Tankers & Dumpers
- More access roads are prepared to reach to the location of fire.
- Area under the fire/Smoke are separated by trenching.
- The trenches are filled up with water.
- Fire tankers/water tankers are always ready at site to douse the fire.
- C & D and other inert material/wet material is spread over the fire
- A fire register is maintained.
- Fire prone areas identified and more care for these areas.
- Restrict the illegal entry including rag pickers. Most of the fires are man created.

Action Plan for Odour Control

- 4 Tractors with special spray jet deployed round the clock to spray Herbal Chemical & Deodrant
- The Chemical and Deodrants are sprayed on the fresh waste, at the location of cutting of waste and at the location of filling of waste.
- These are being sprayed on internal roads at regular interval.
- Laying of daily cover of C&D on the fresh waste also reduces the odour.

SPRAYING OF CHEMICAL ON REFUSE AT LOOP NO - 8

TOP SOIL COVERING OVER FRESH MSW AT LOOP NO - 8

Laying of Cover System on Sloping Area

Laying of Cover System on Sloping Area

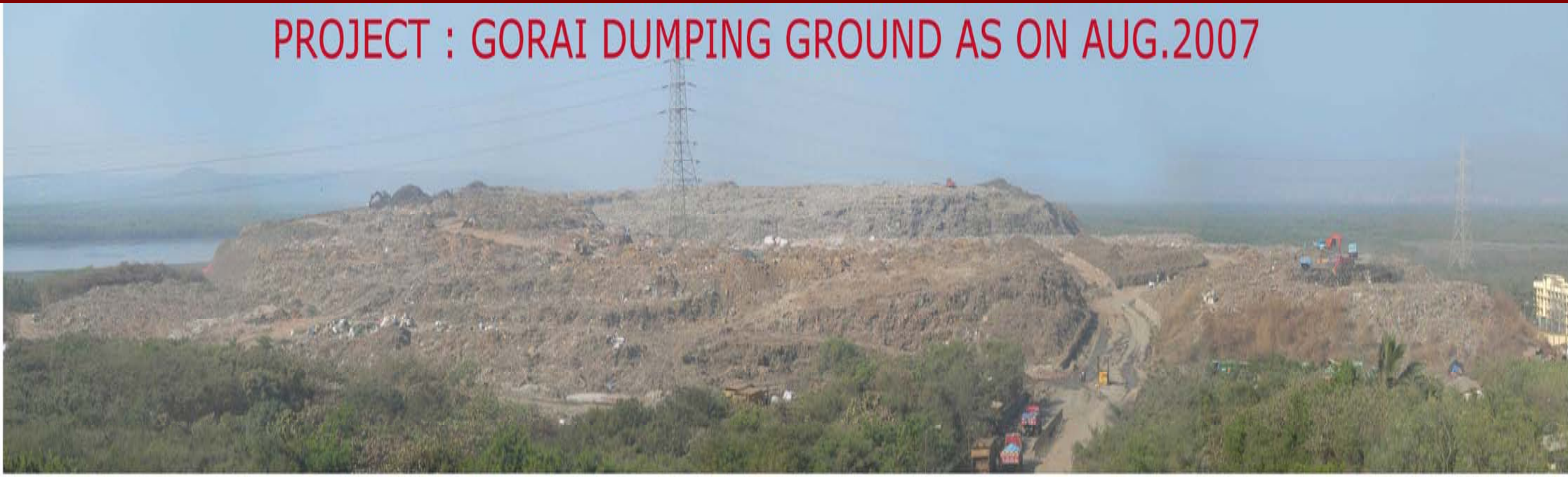
Laying of Cover System on Top Flat Area

Laying of Cover System

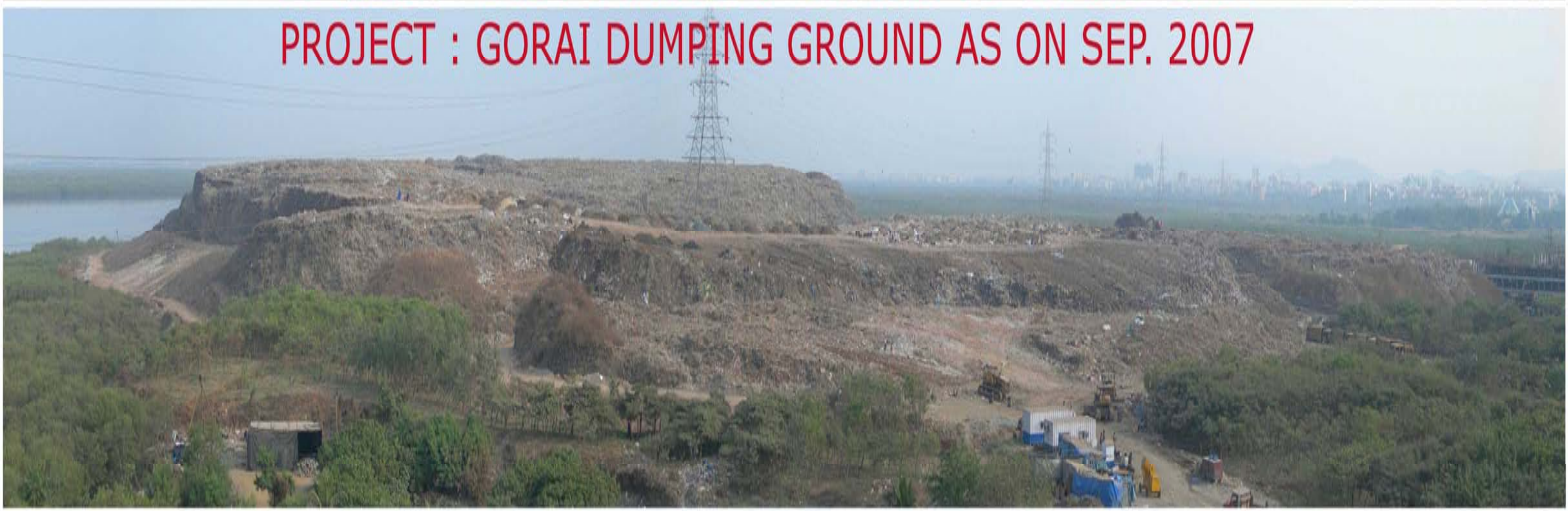
Development of Greenery

Construction of Gas Well

Gas Flaring System



PROJECT : GORAI DUMPING GROUND AS ON AUG.2007



PROJECT : GORAI DUMPING GROUND AS ON SEP. 2007

Gorai Dump Site


PROJECT : GORAI DUMPING GROUND AS ON AUG. 2008


PROJECT : GORAI DUMPING GROUND AS ON SEP. 2008

PROJECT : GORAI DUMPING GROUND AS ON AUG. 2009

Control Measures at Devnar Waste Dump (Landfill), Mumbai

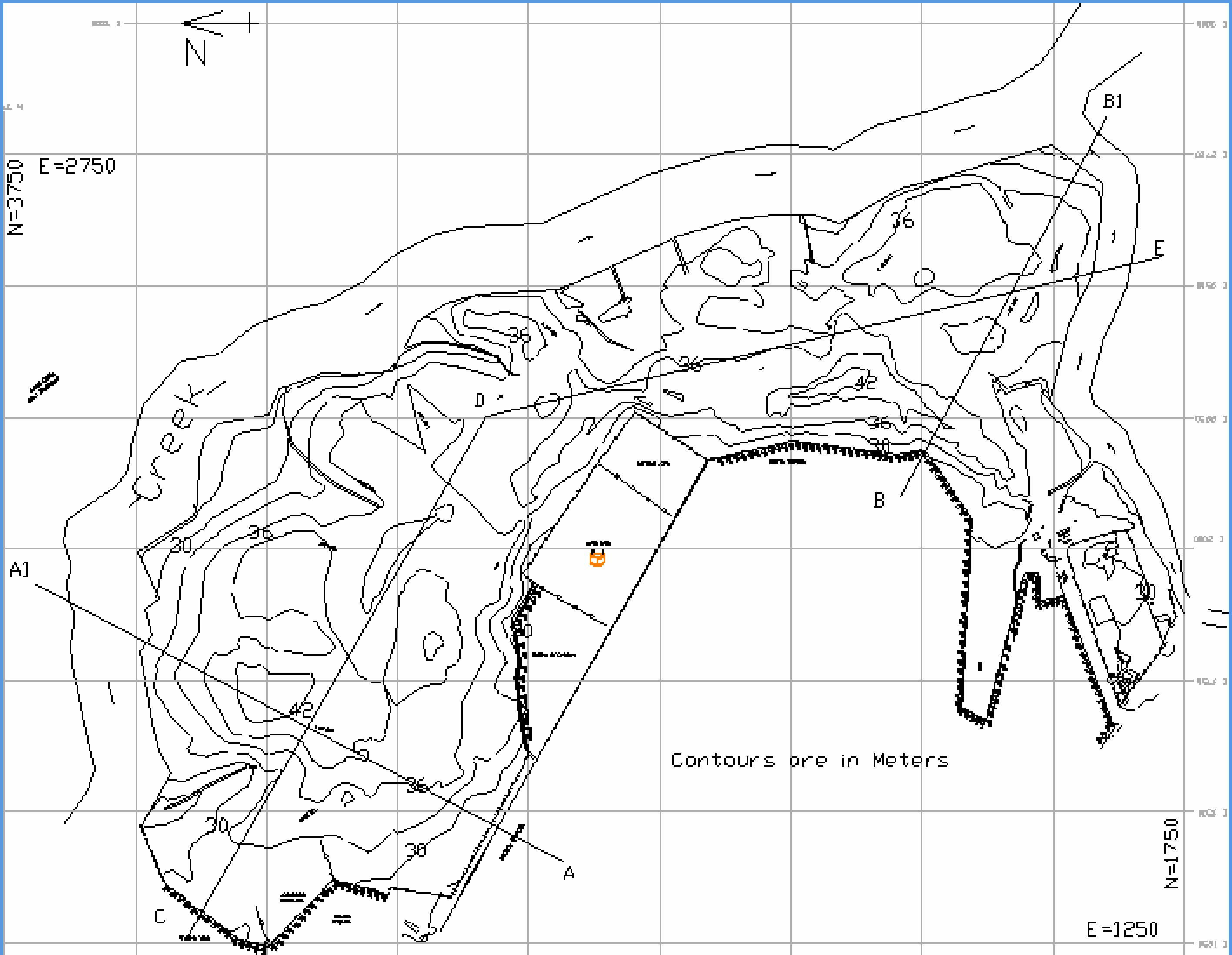
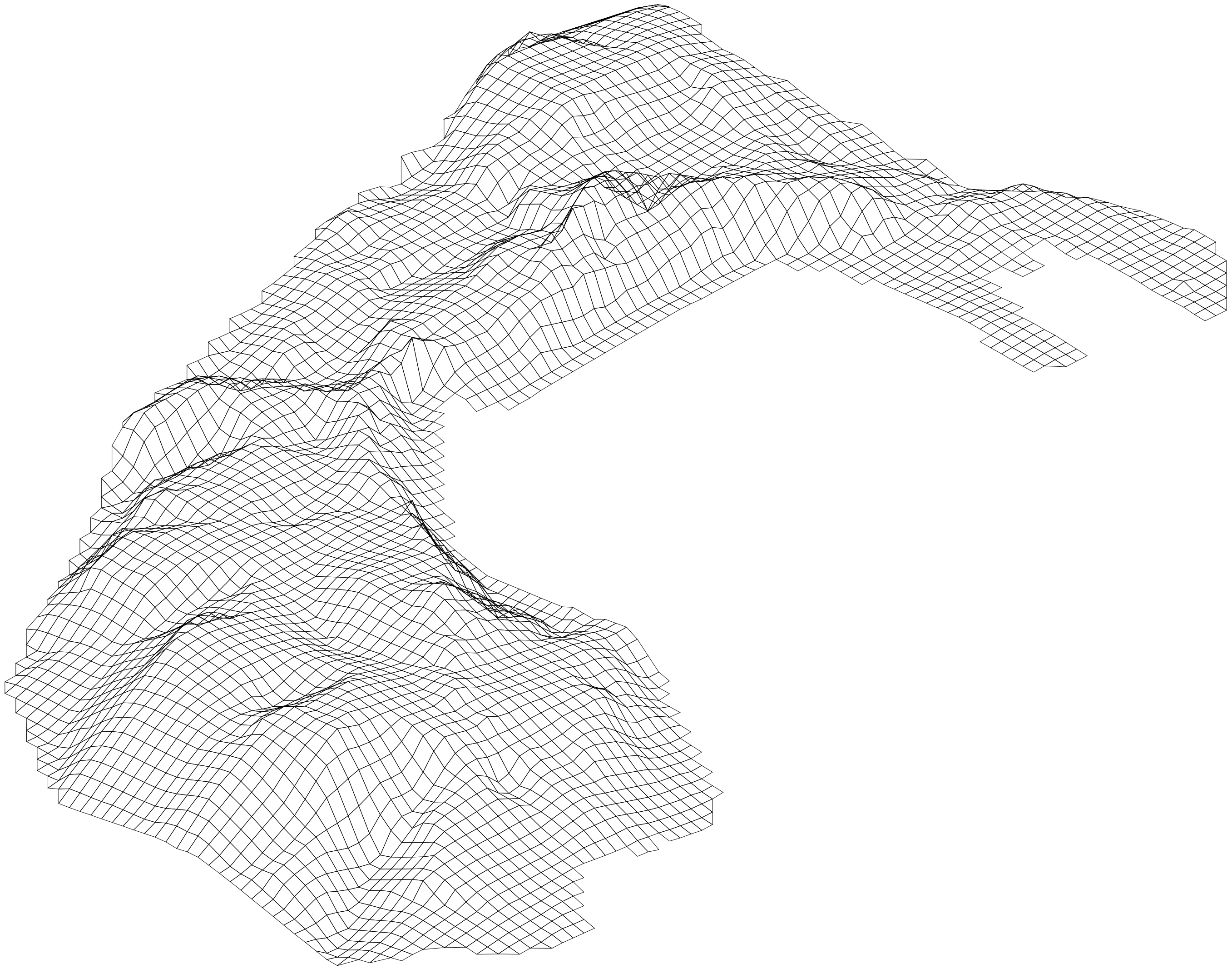


Fig1: PLAN VIEW OF EXISTING WASTE DUMP



Waste Piles

Roads on Top of Waste Dump

Burning Waste

Ponding of Leachate

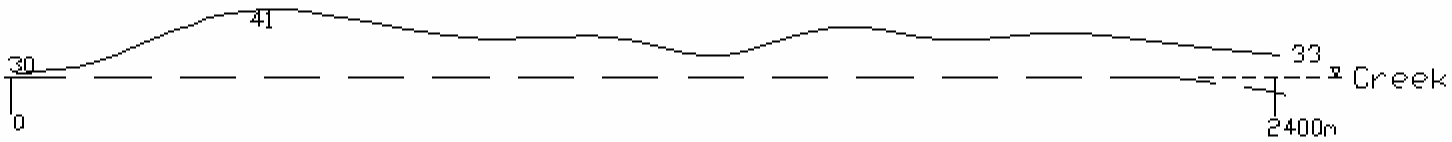


Fig3: SECTION OF EXISTING WASTE DUMP ALONG C-D-E

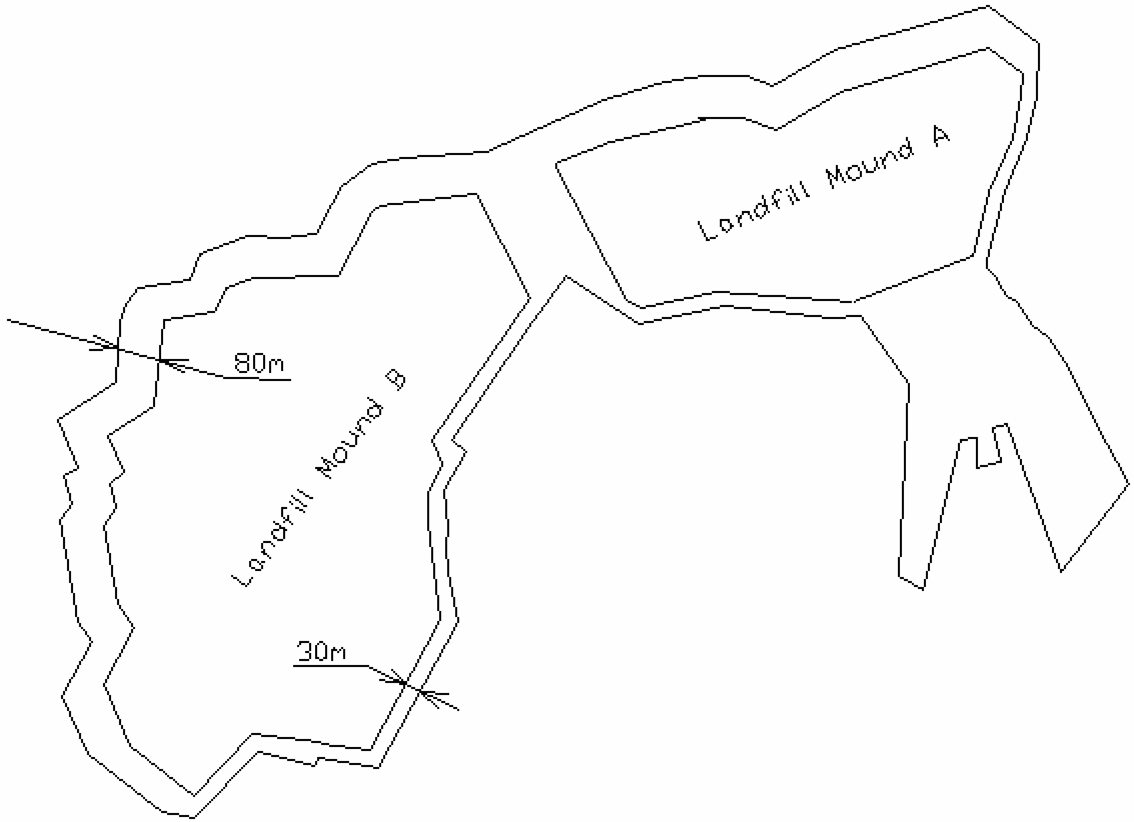
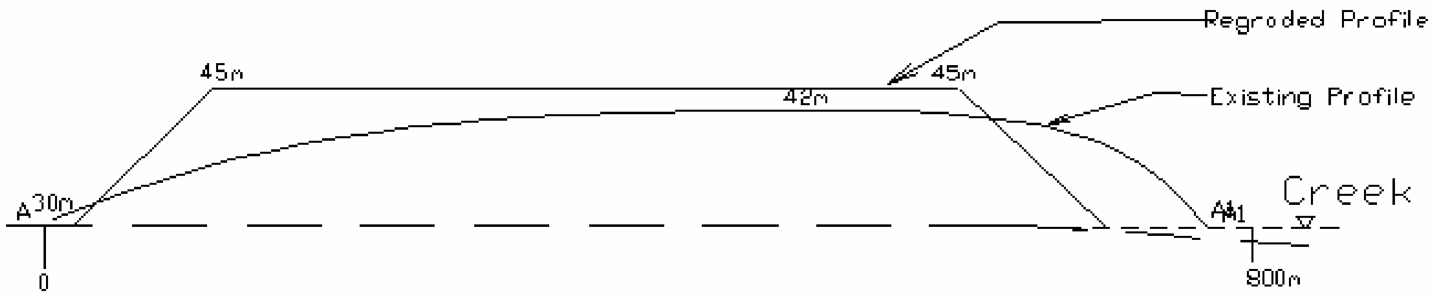
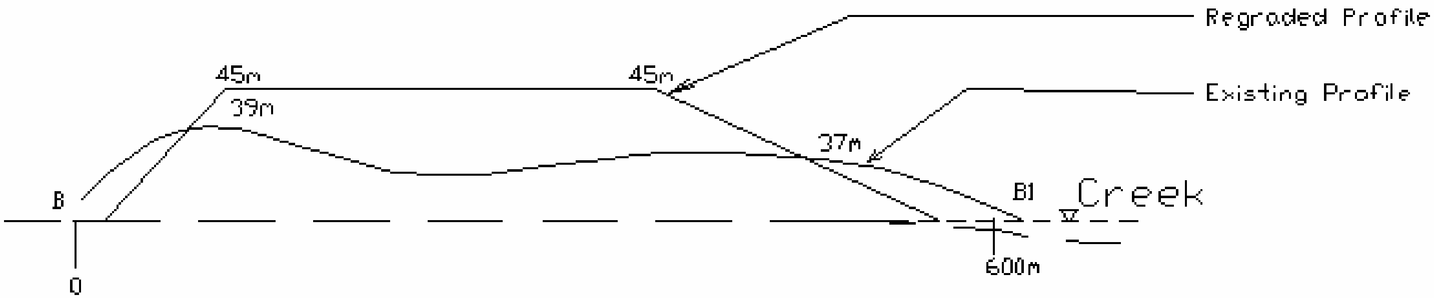


Fig4: PLAN VIEW OF LANDFILL BASE AFTER COMPLETION



(a) Section A-A1



(b) Section B-B1

Fig5: REGRADED SLOPES

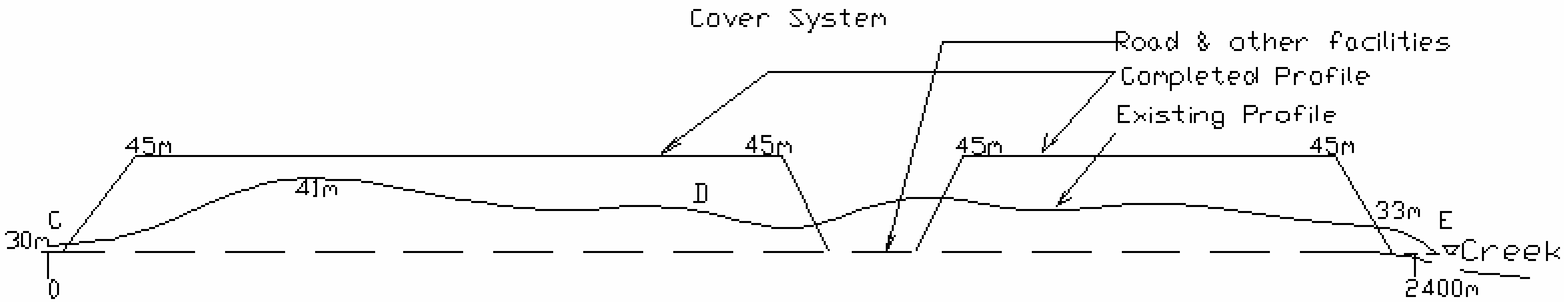
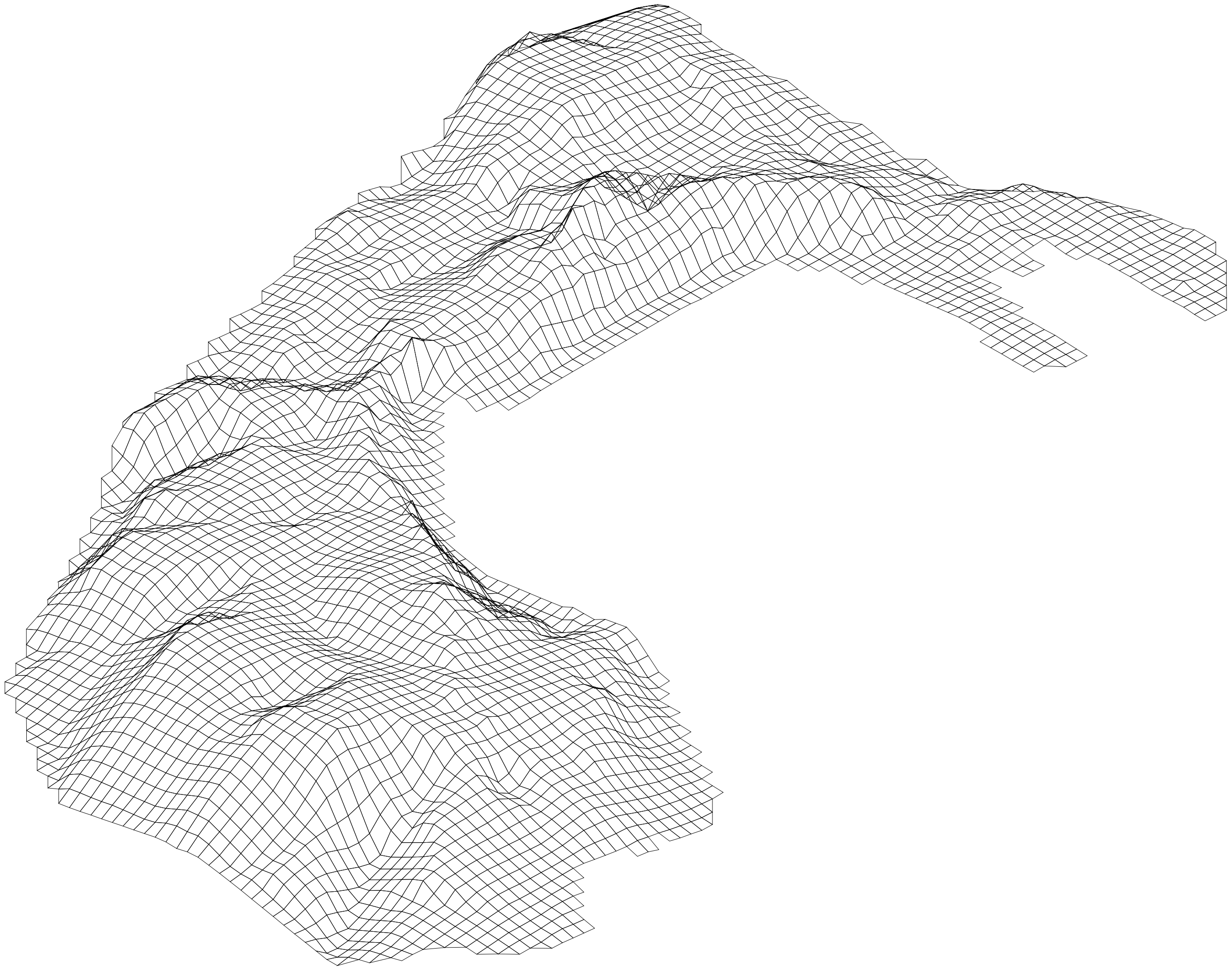
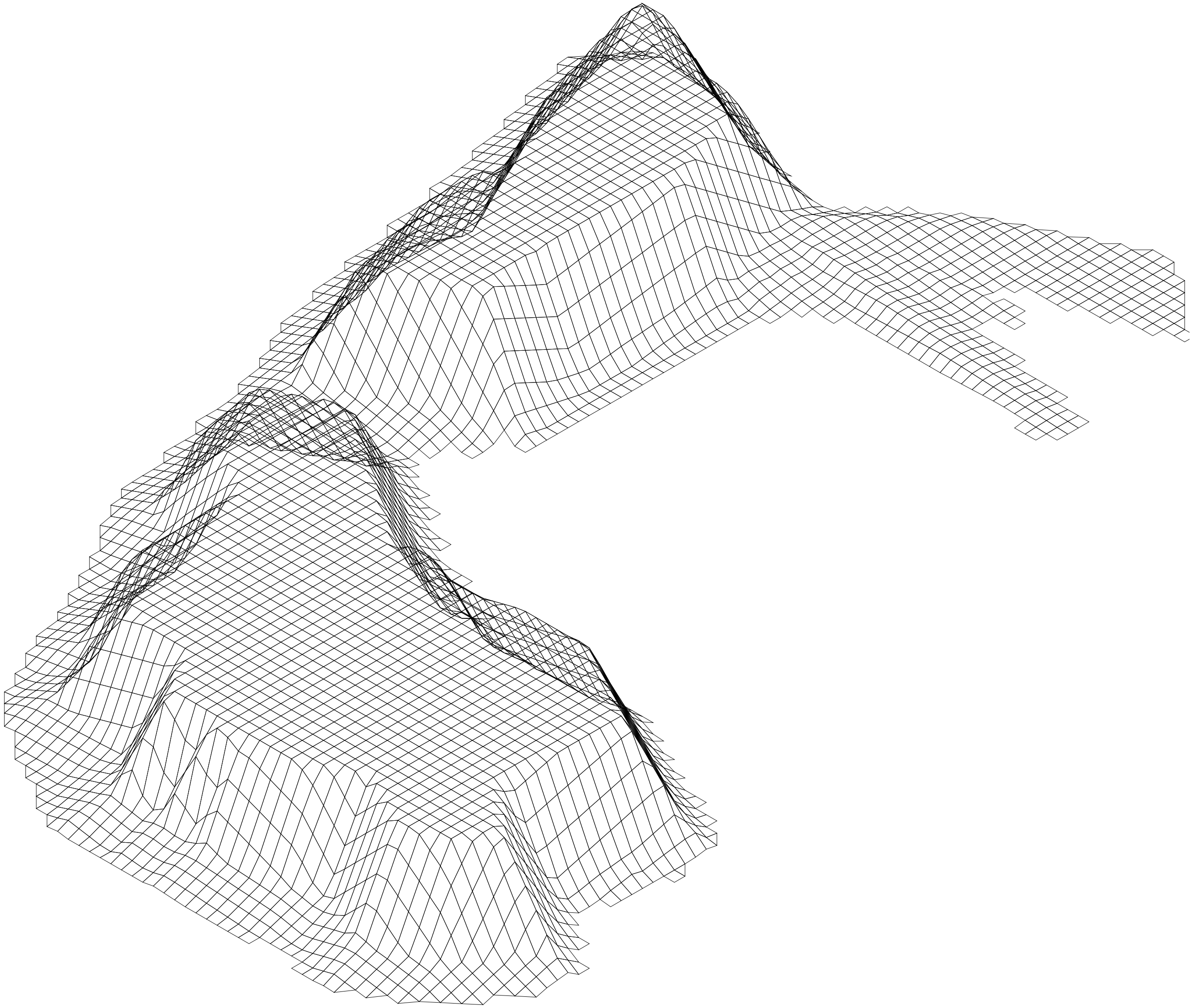
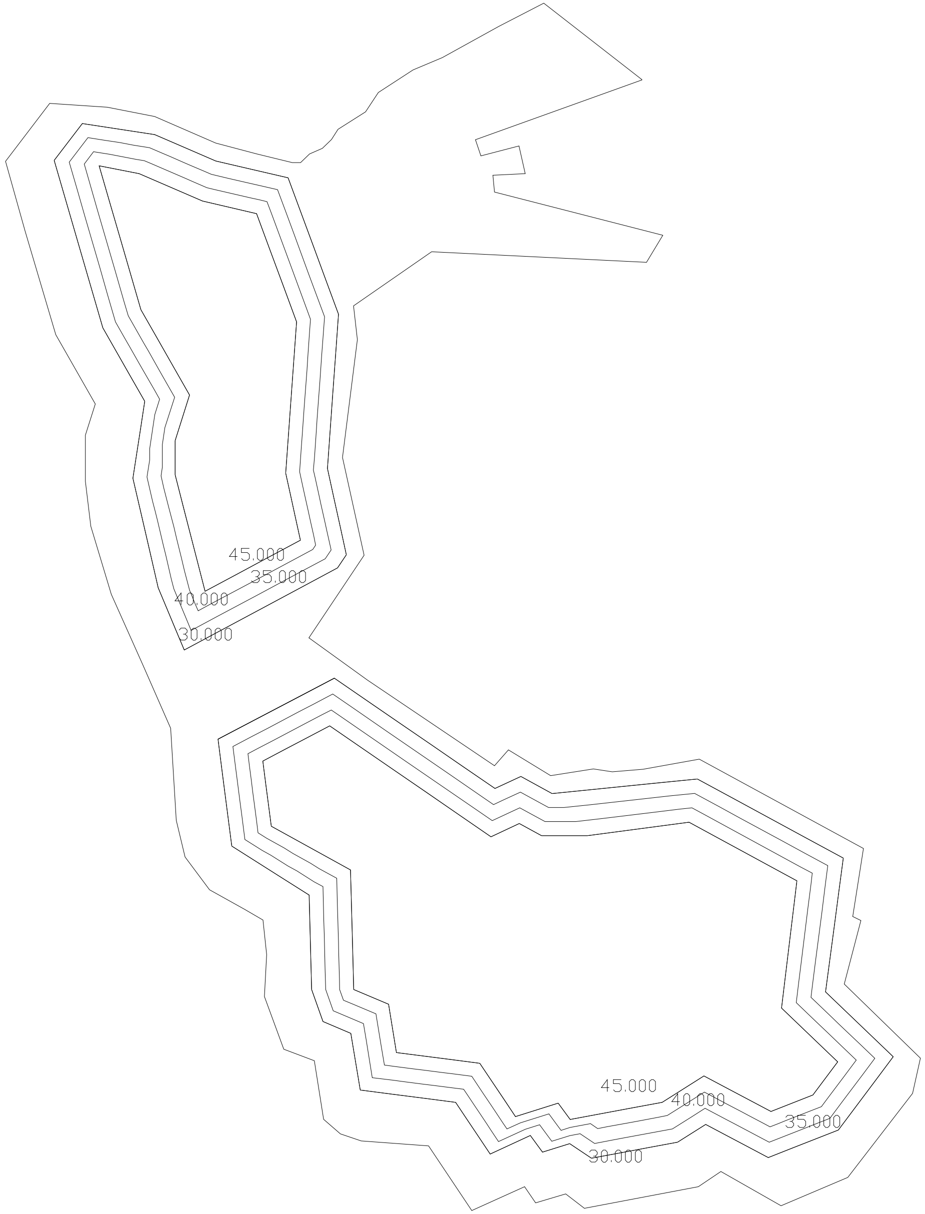


Fig6: REGRADED SLOPES AND COMPLETED LANDFILL
(Section C-D-E)







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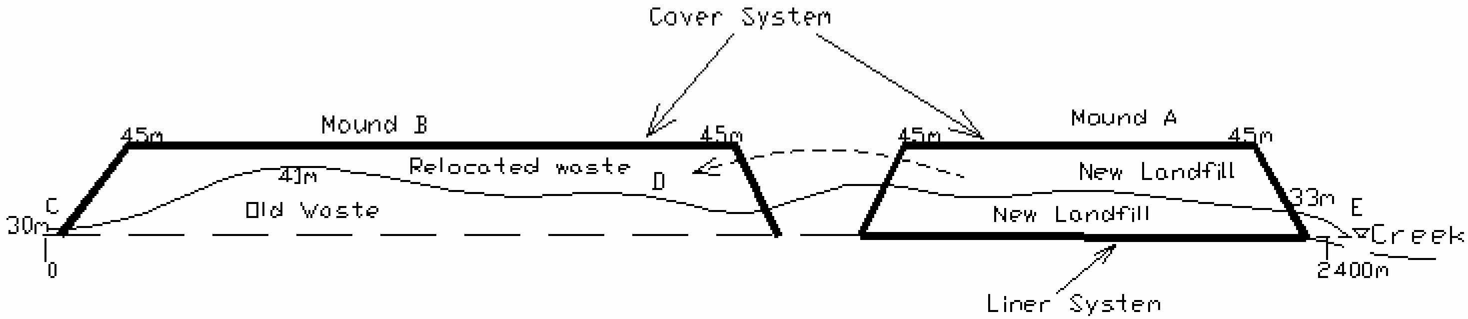
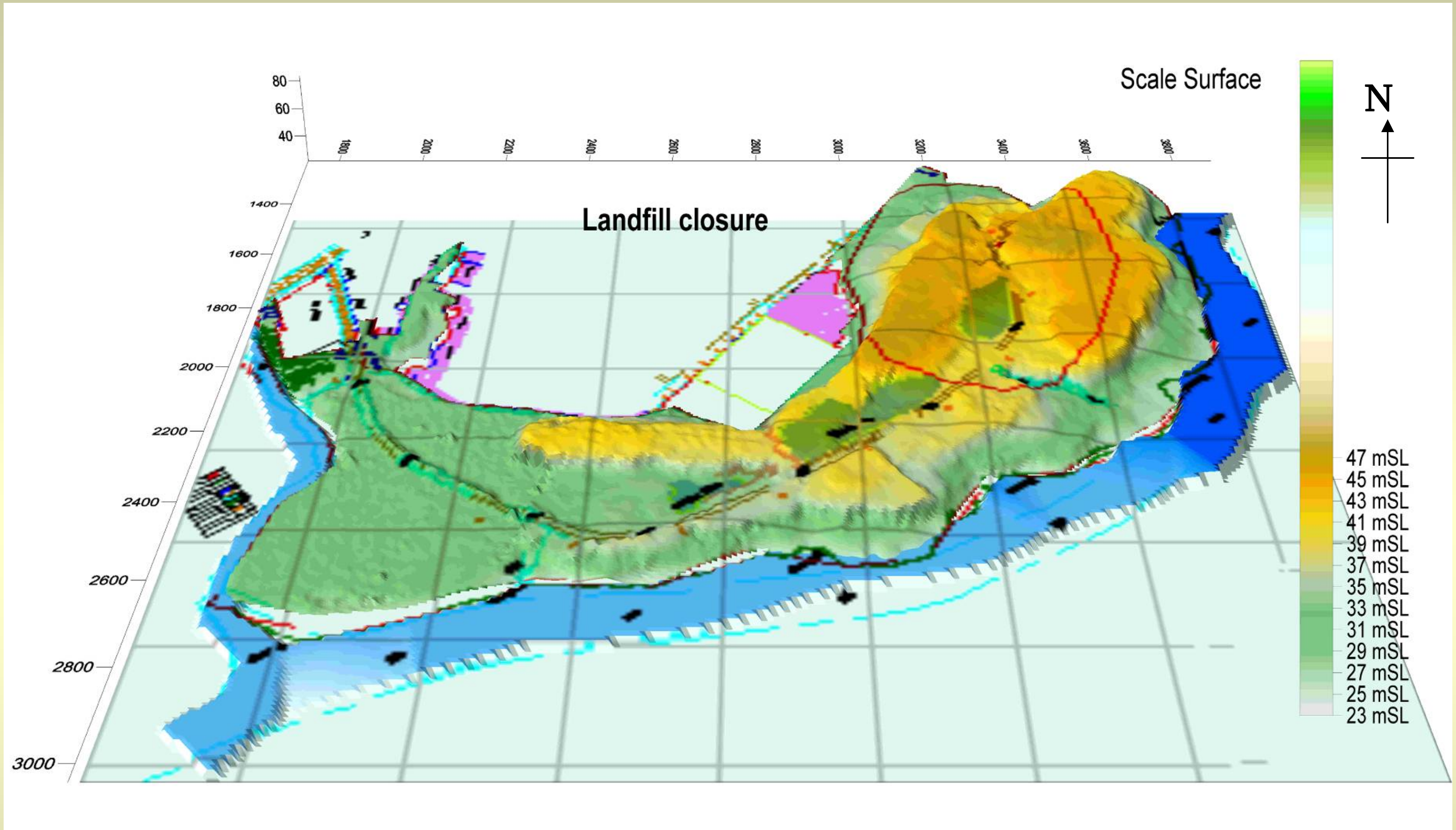


Fig9: OPTION B FOR WASTE FILLING

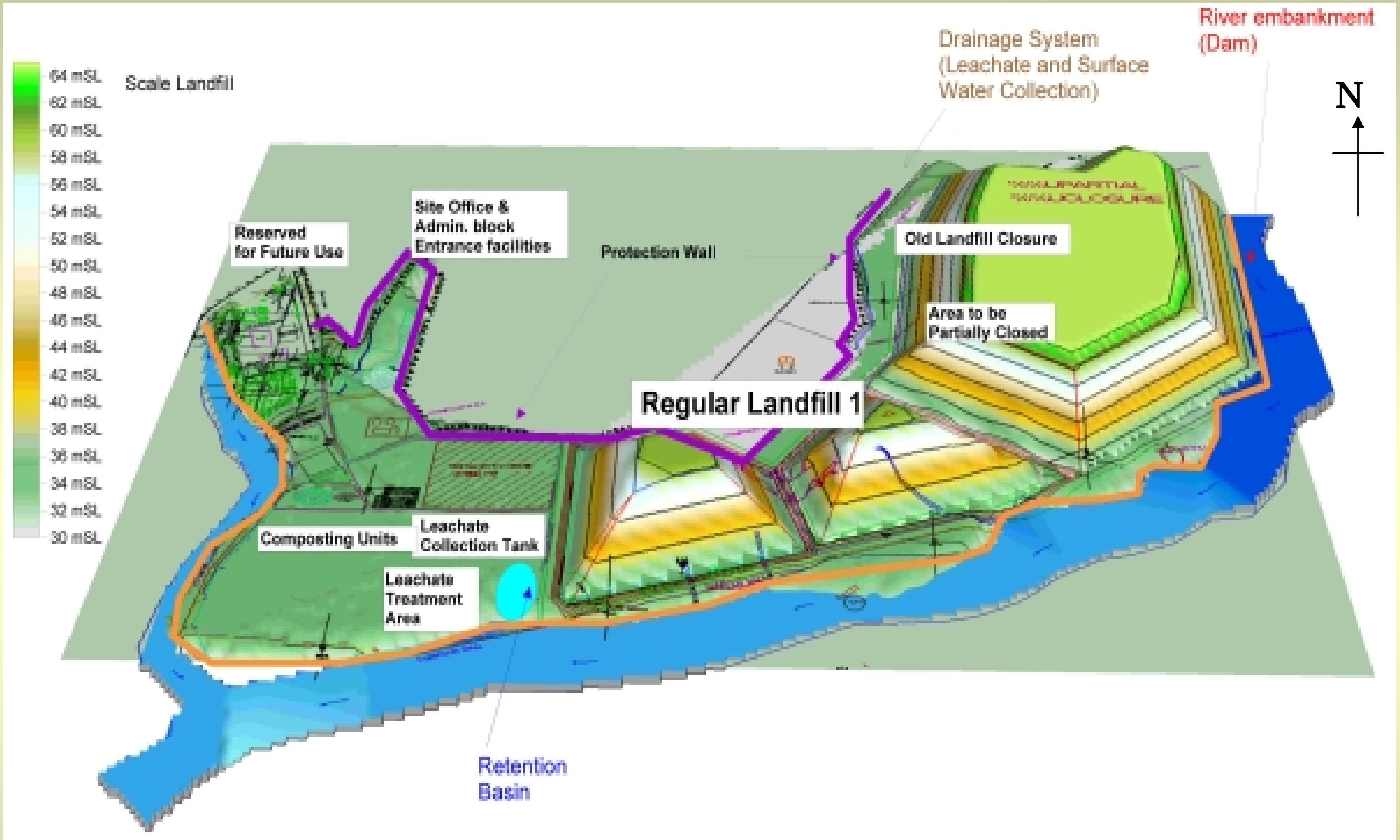
Area demarcation and Planning

- Identification of foot print area based on the contour survey and actual waste to be accommodated
- Demarcating the various activity zone with help of permanent markers

- Phasing and scheduling the shifting of waste and reformation work.
- Planning for receipt of daily waste.



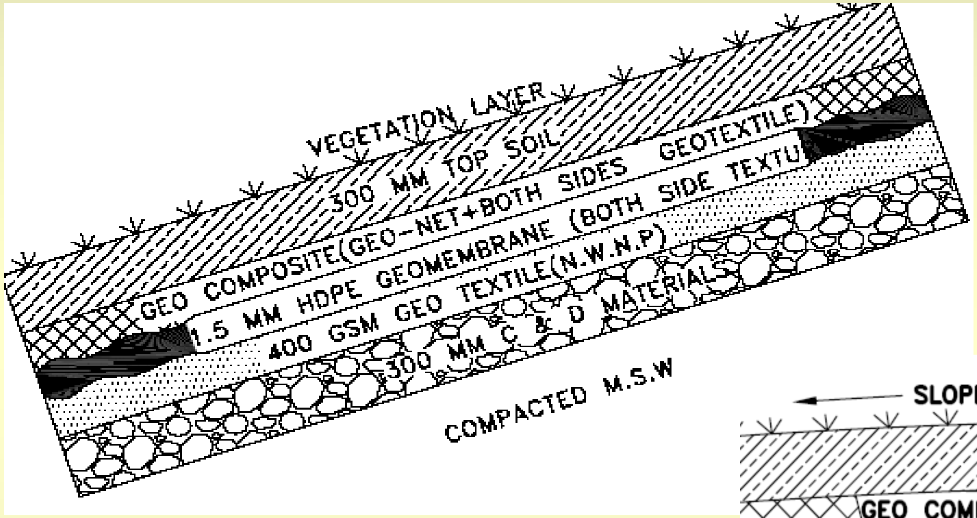
3D model of Deonar site based on RfP data



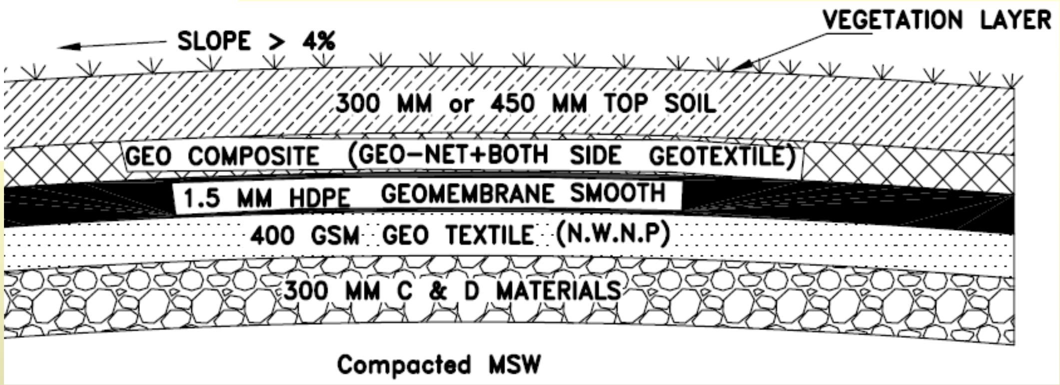
Conceptual 3D model of Deonar site

Proposed cover system

Based on our experience of past projects we have adopted the following liner system for estimation purpose



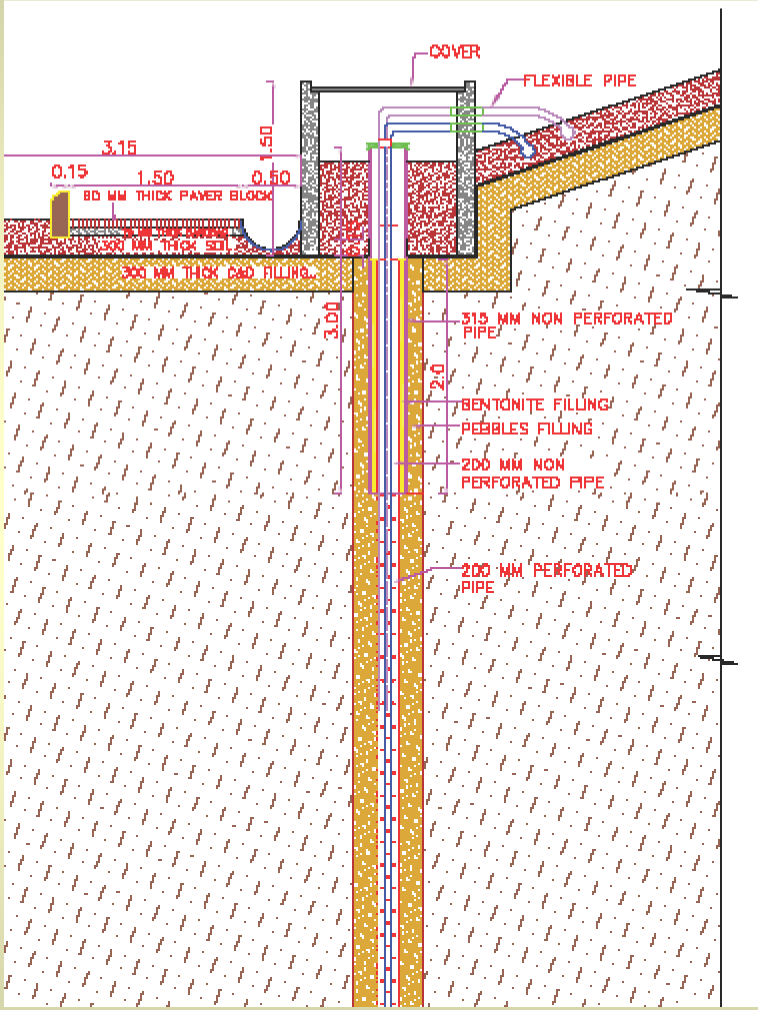
For Slope



For Flat Surface

However the final cover system will be finalized during the detailed designing.

Details of Gas/Dual Wells

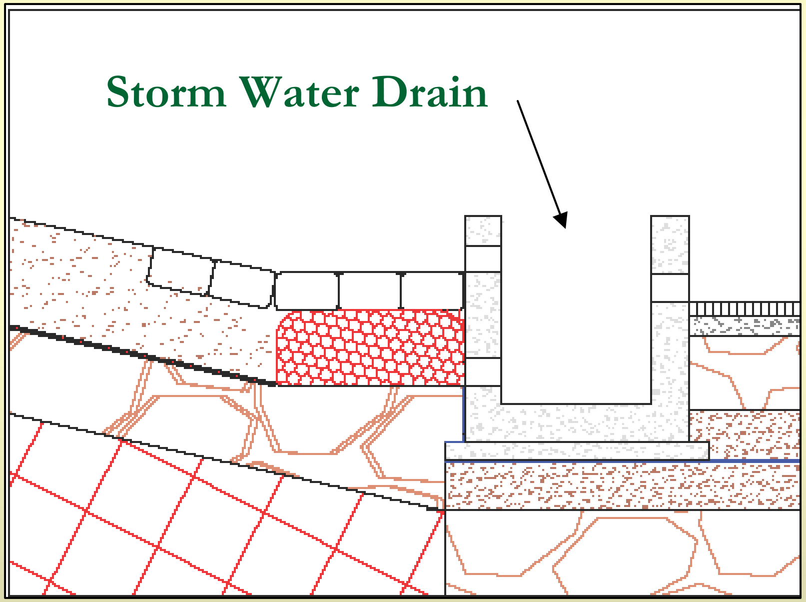


Dual Well Section

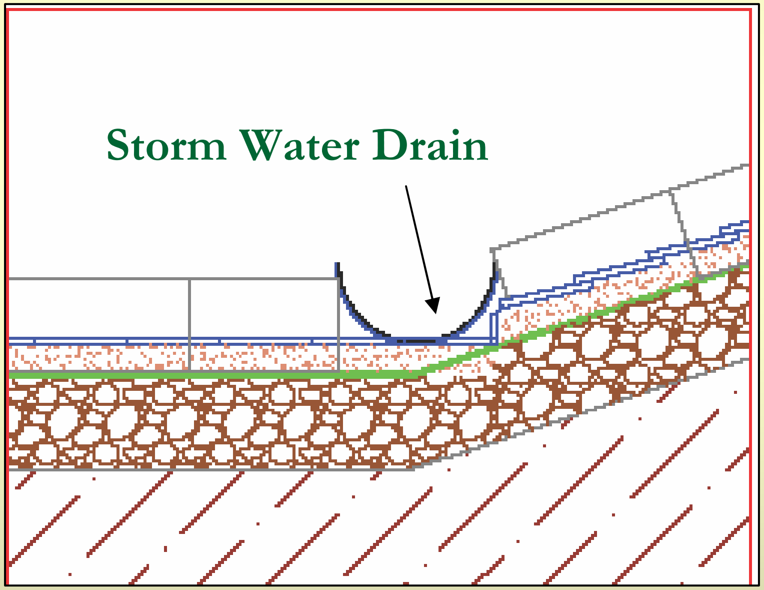
Construction Procedure followed at one of our sites

Storm water drainage system

- Based on the meteorological data the storm water drain will be designed.
- While designing the storm water drain the concept will be to catch the rain water as early as possible.

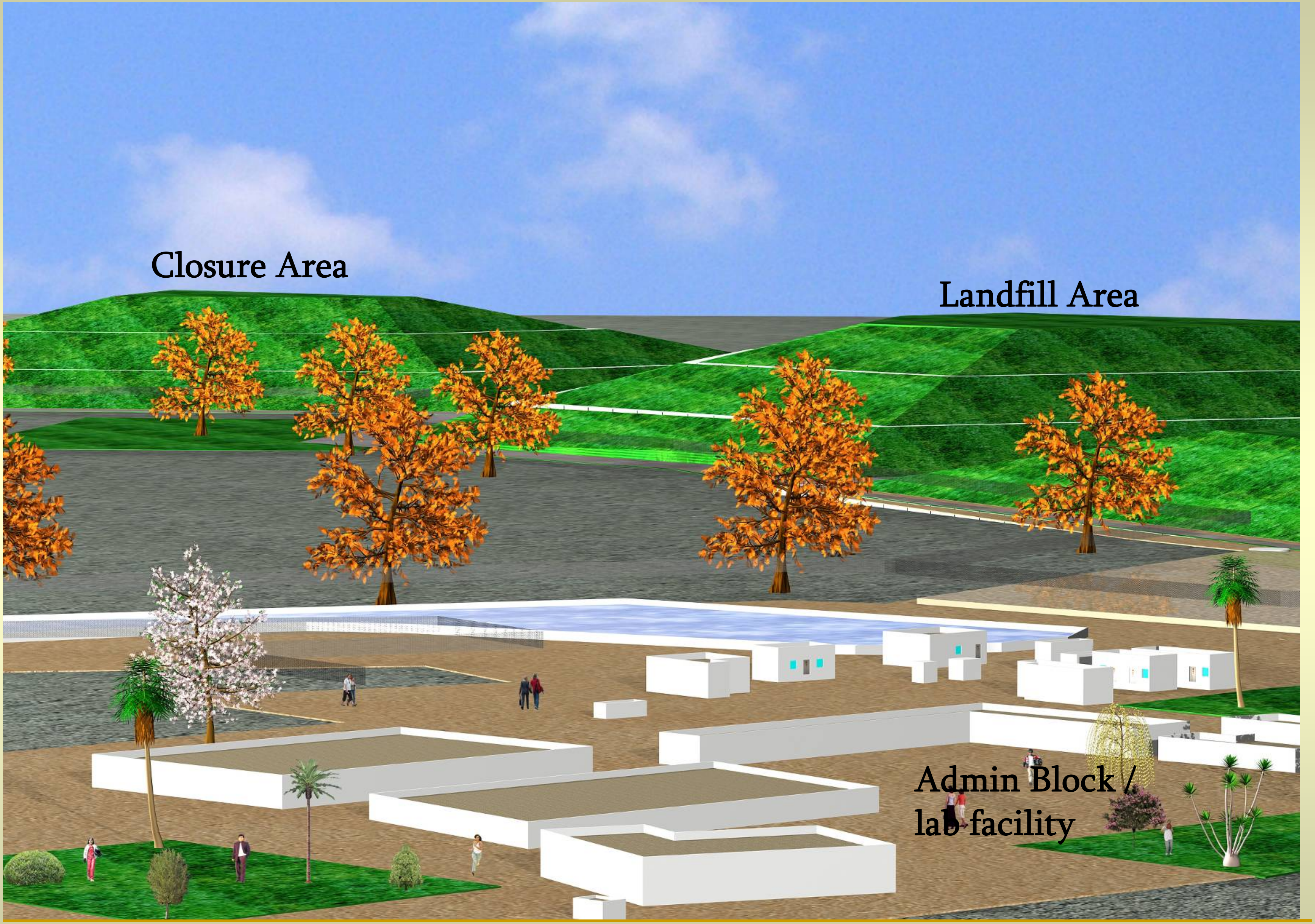


Storm Water Drain at Toe



Storm Water Drain at Berms

N
Partial Closure Area
Boundary wall on landward side
Site entry
Parking area
Approach road
Internal road
Emergency Landfill
Landfilling Area
Admin/Lab Block
Compost Plant
Peripheral bund (with core wall)
Peripheral bund (without core wall)
Leachate treatment facility


Closure Area
Landfill Area
Admin Block /
lab facility

Liner system

Bottom Liner

450 mm Drainage Layer- C&D
Geo-textile 350gsm
1.5 mm HDPE Geo-membrane
Clay liner / GCL

Top Liner

150 mm Vegetative layer
300 mm Soil layer
150 mm Drainage Layer- C&D
Geo-textile 350gsm
1.5 mm HDPE Geo-membrane
Clay liner / GCL
450 mm C&D layer- Gas venting Layer

Case Study : Ghazipur Landfill


FREIGHT COMPLEX GAZIPUR
गाजीपुर पॉकेट ए
GAZIPUR PKT. A
मुर्गा एवं अण्डा मार्किट
CHICKEN & EGG MARKET
MARKET

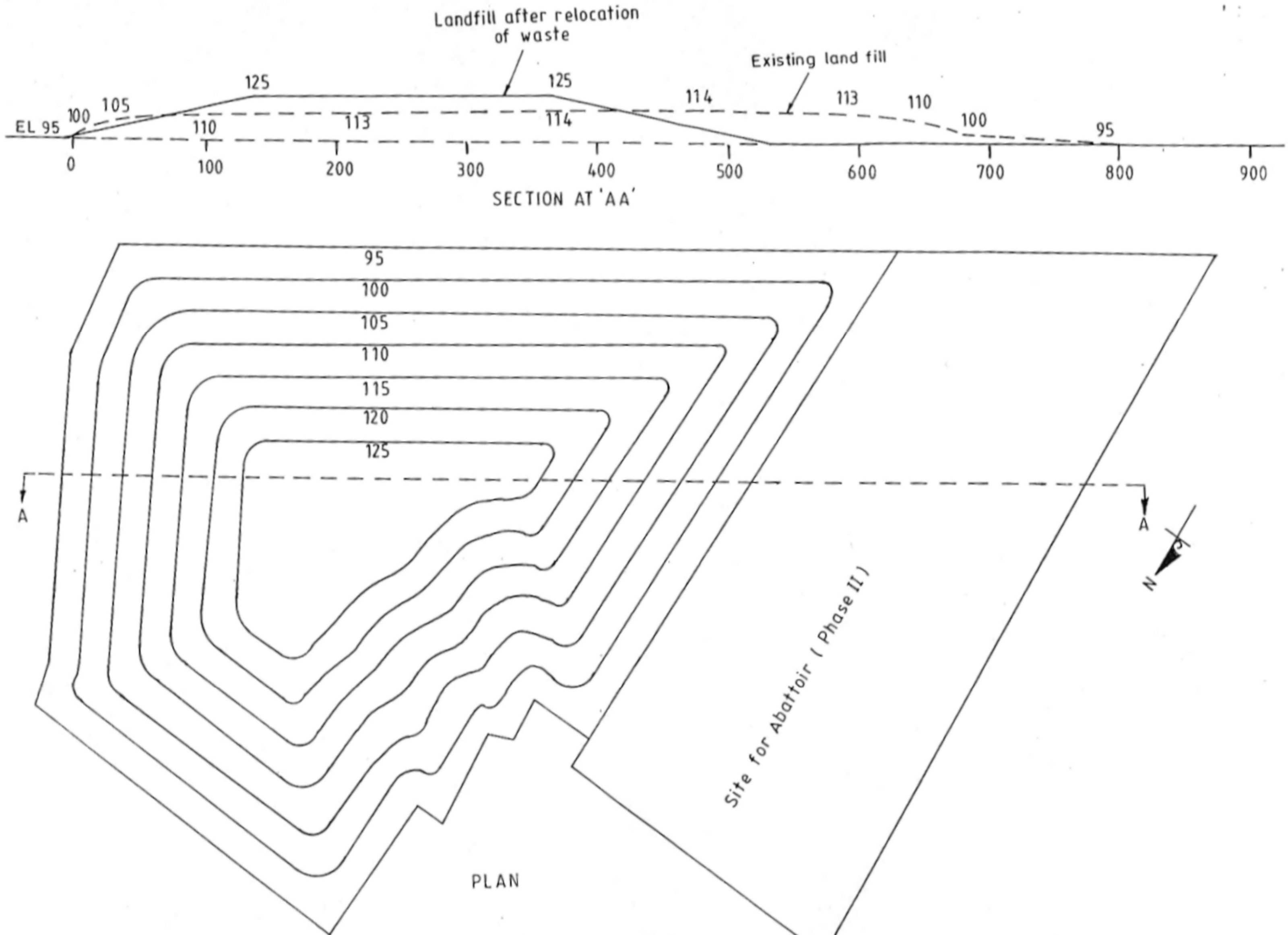


Fig. 2 PLAN AND SECTION OF LANDFILL AFTER RELOCATION OF WASTE.

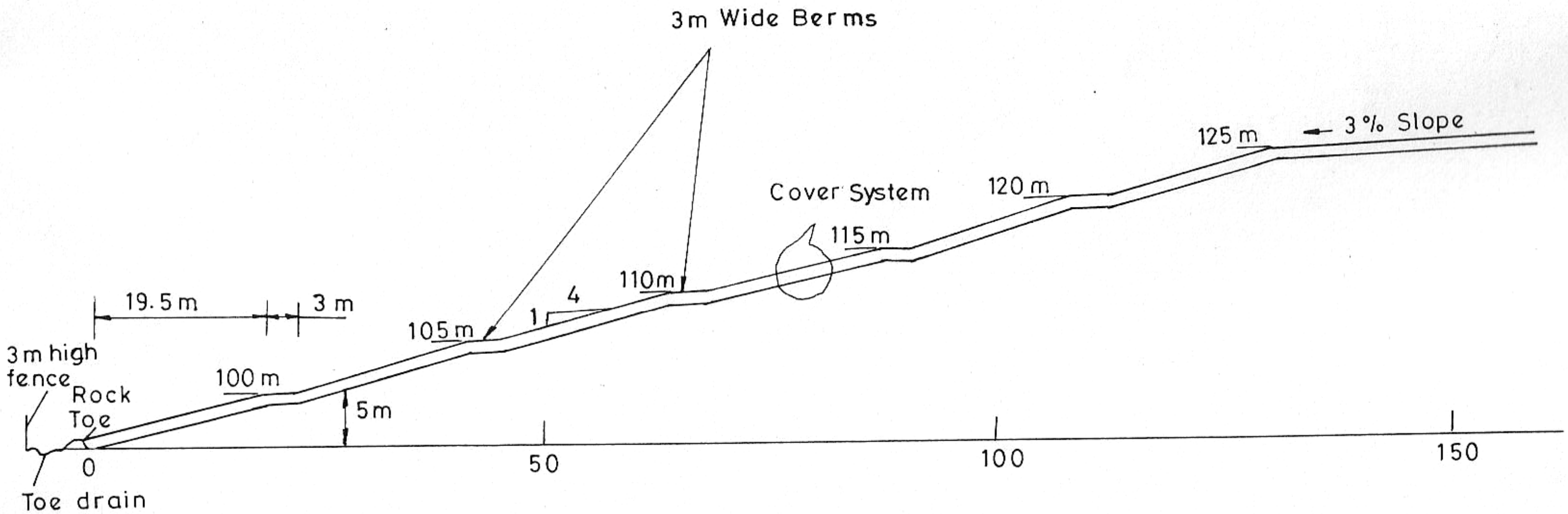


Fig. 3 SECTION OF LAND FILL

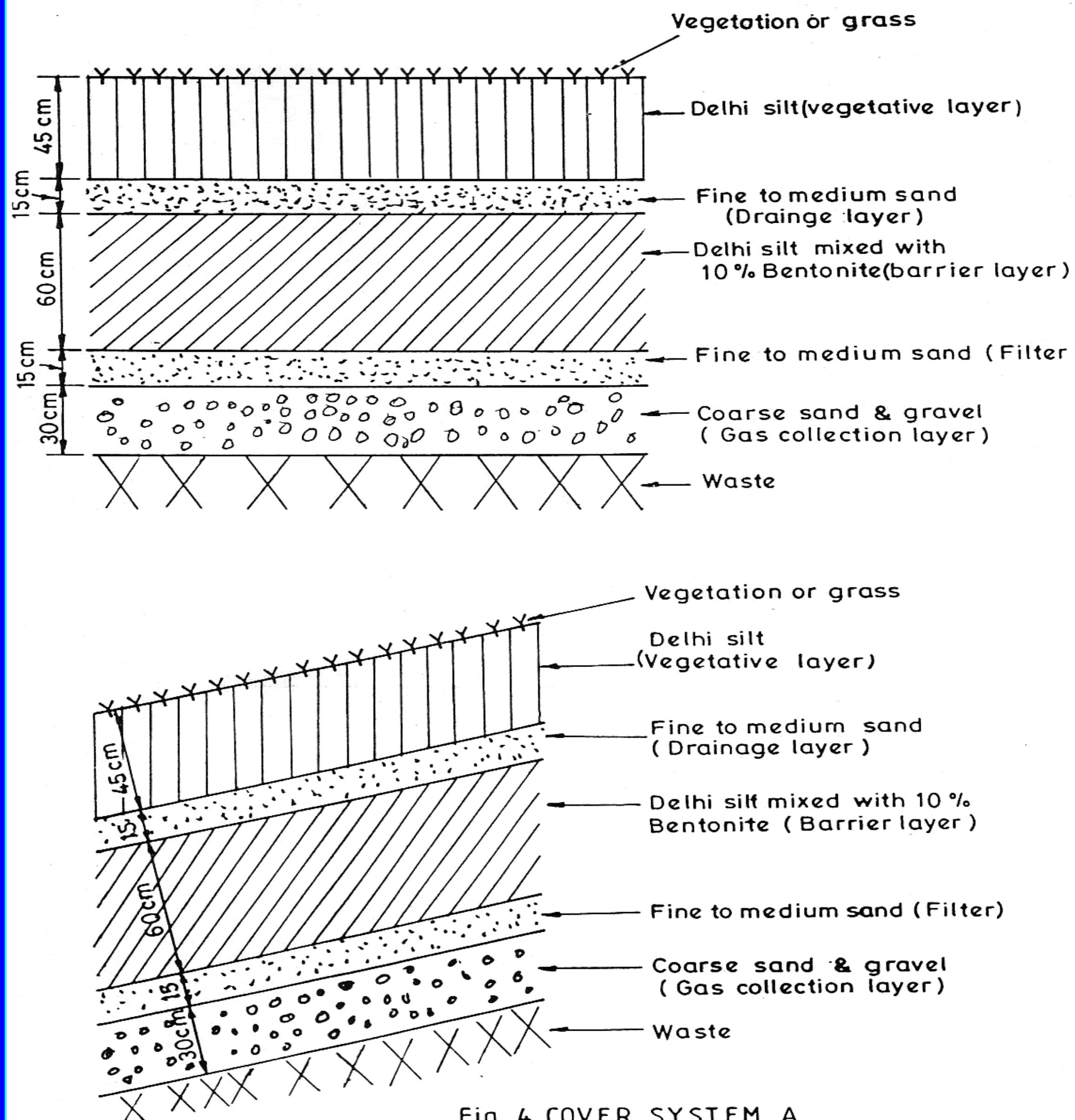
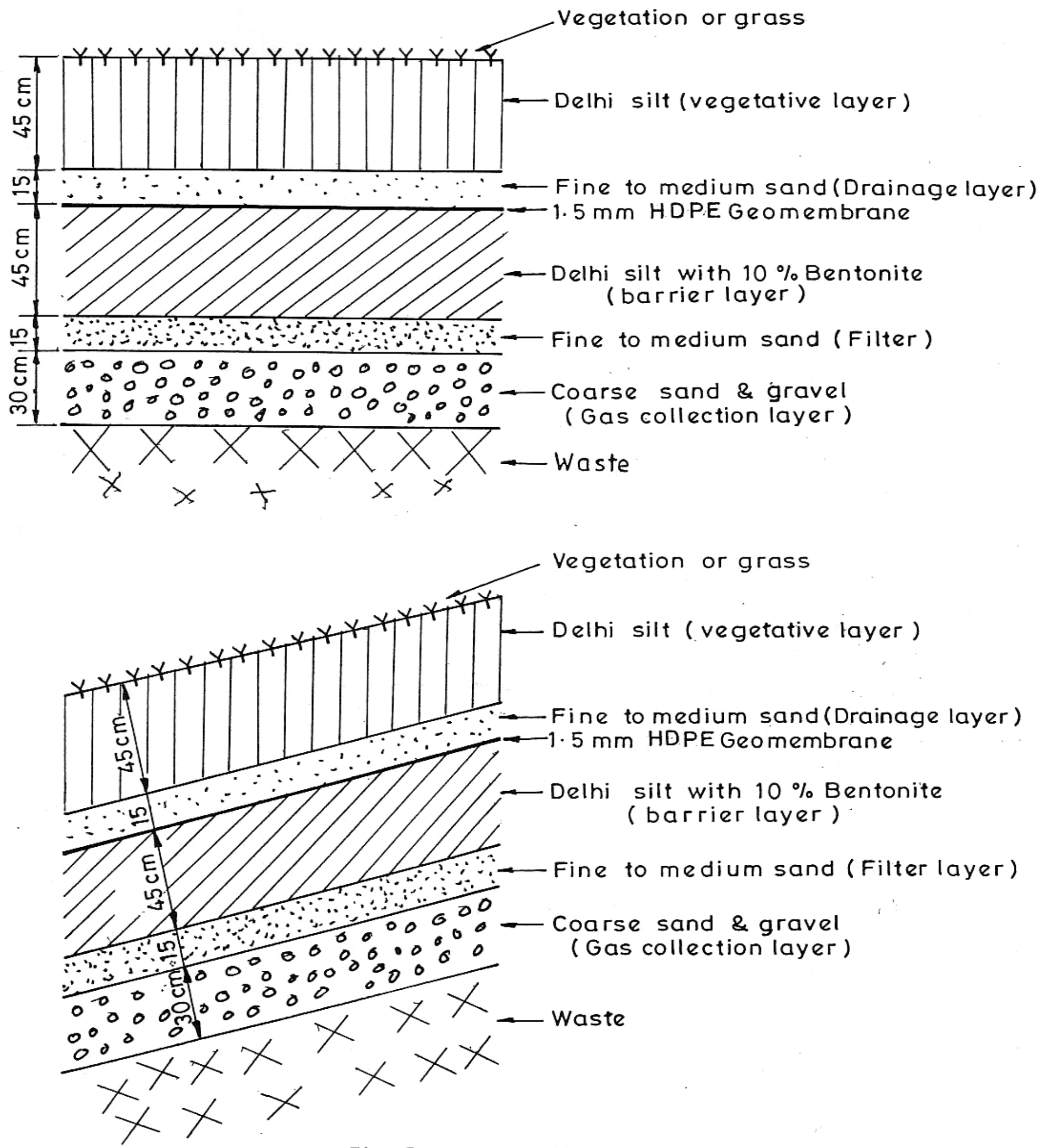


Fig. 4 COVER SYSTEM A



Fig·5 COVER SYSTEM–B

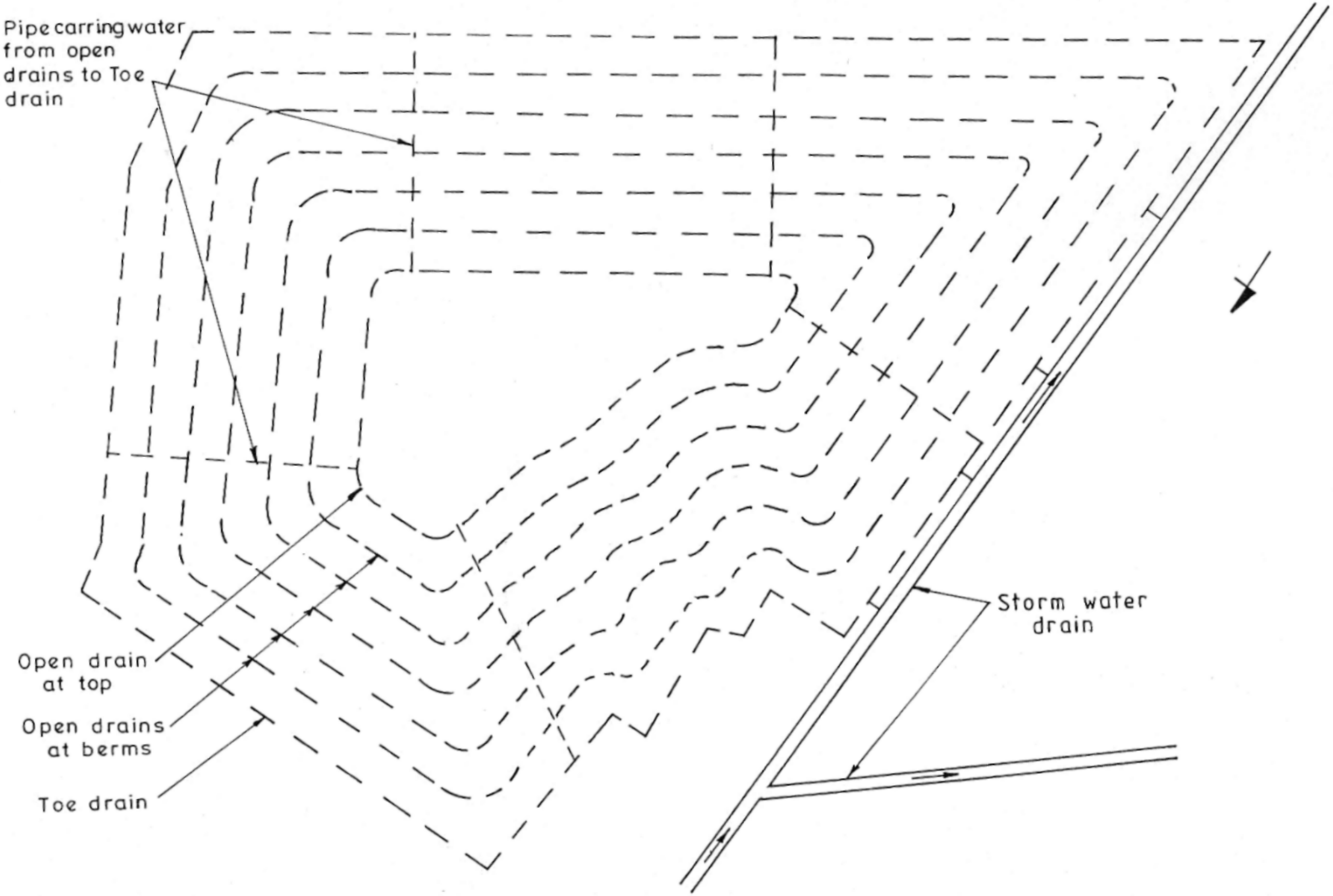


Fig. 11 LOCATION OF DRAINS.

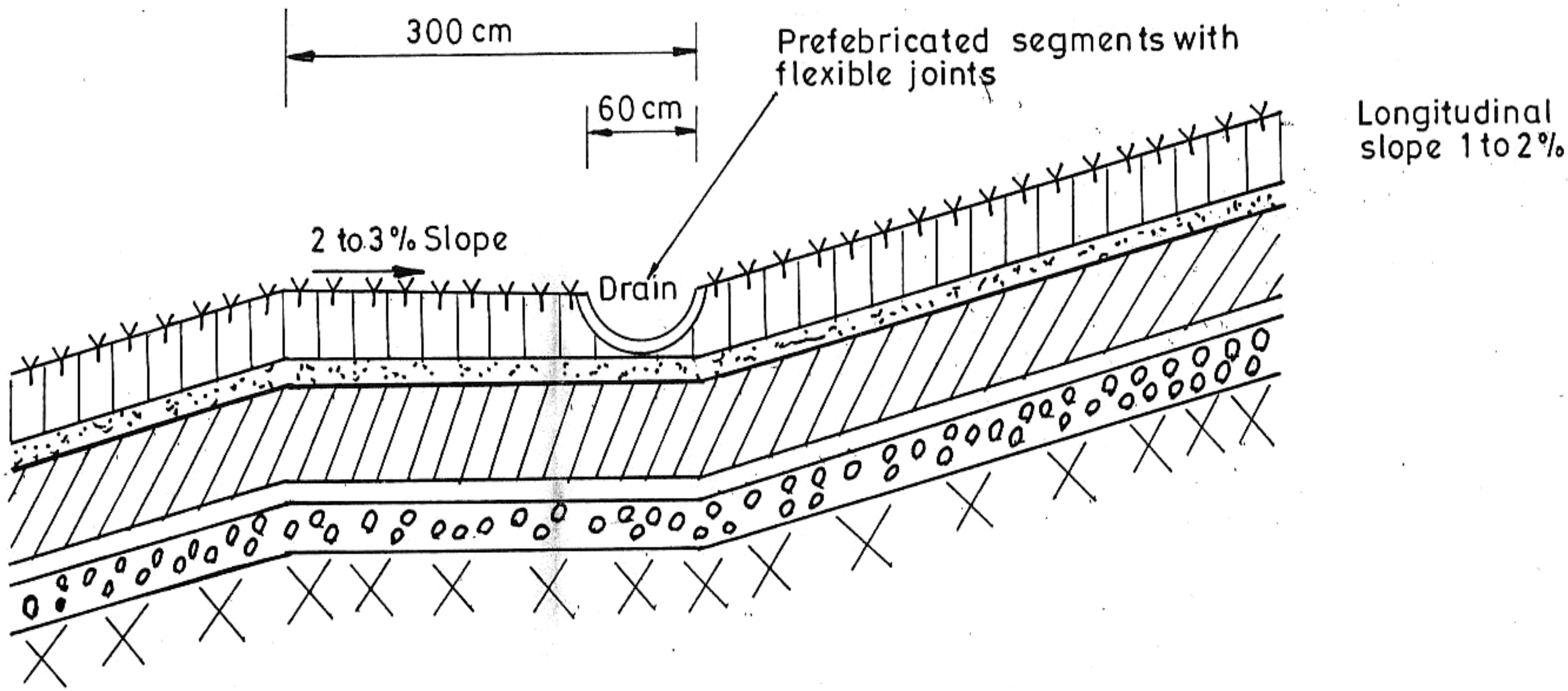


Fig. 9 DRAINS AT BERMS

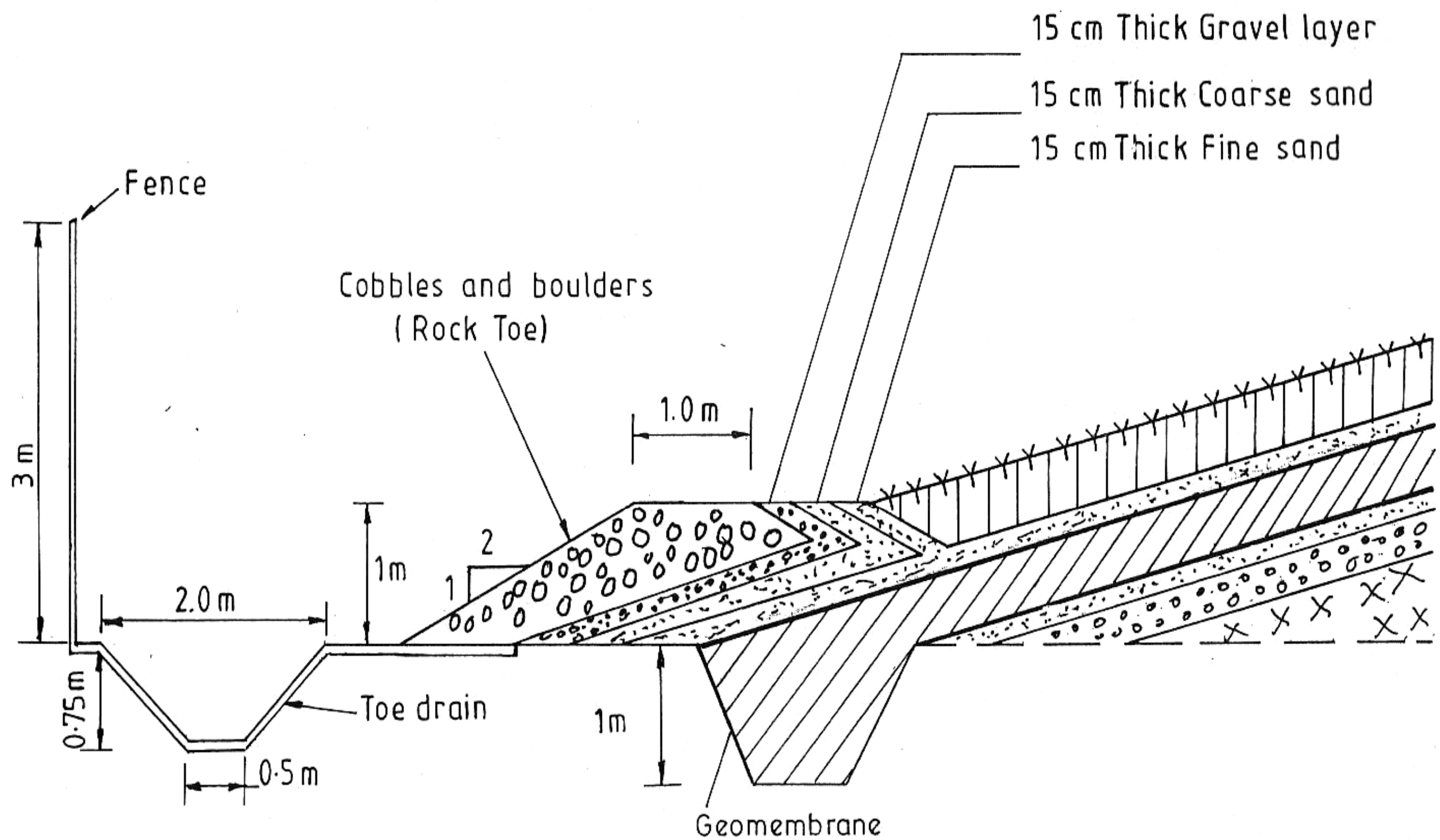
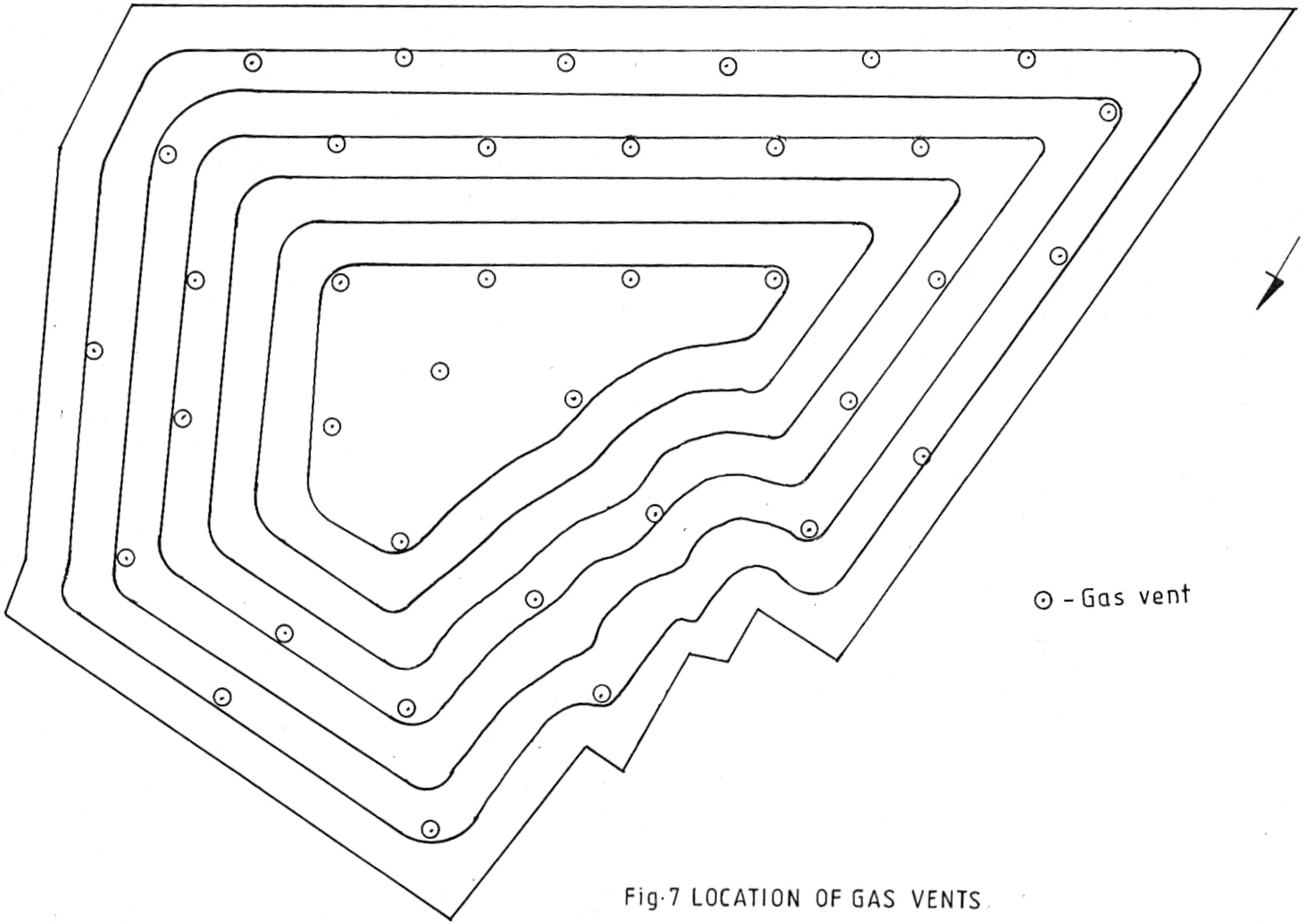


Fig. 10 DETAILS OF ROCK TOE AND TOE DRAIN.



Fig·7 LOCATION OF GAS VENTS

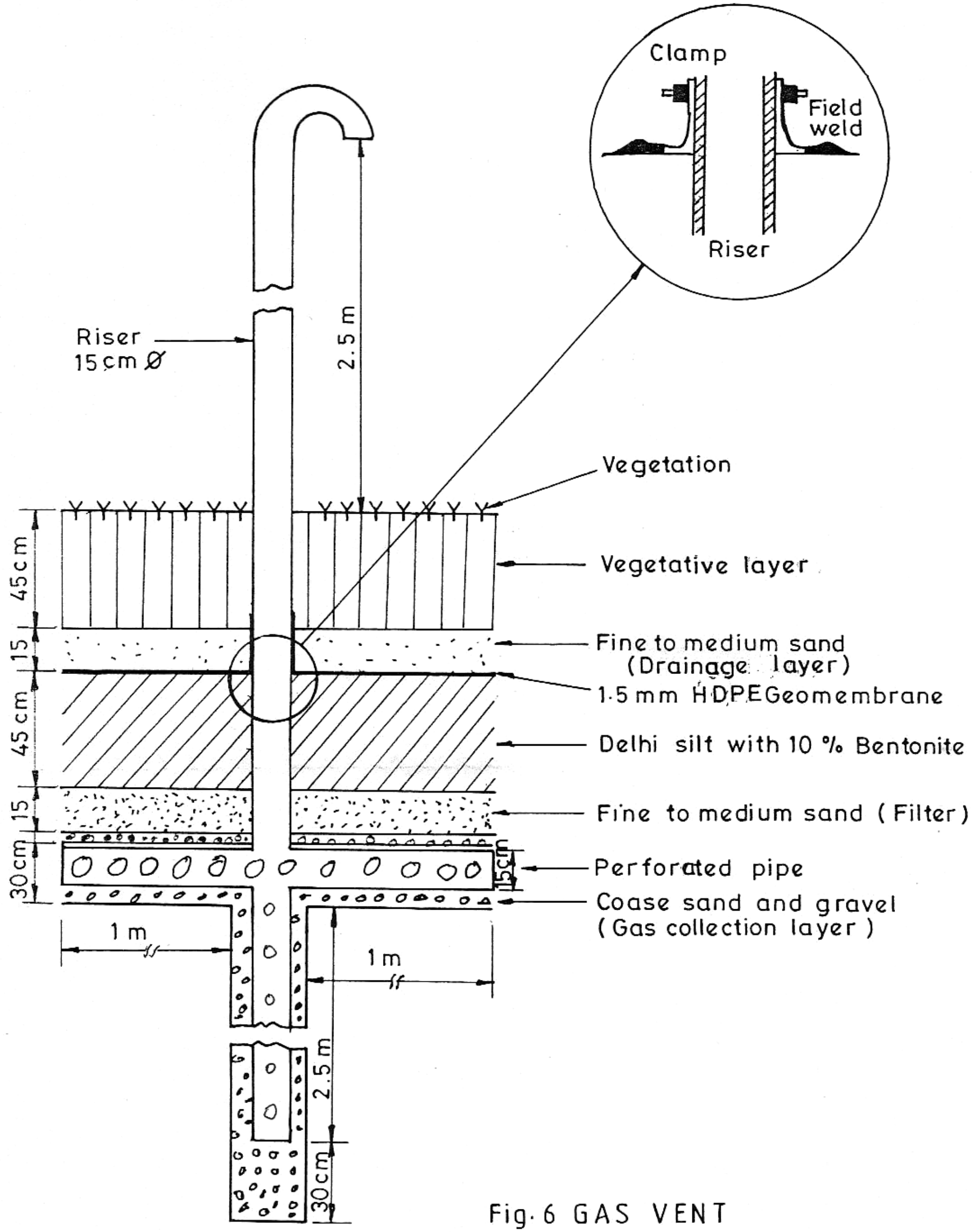


Fig. 6 GAS VENT

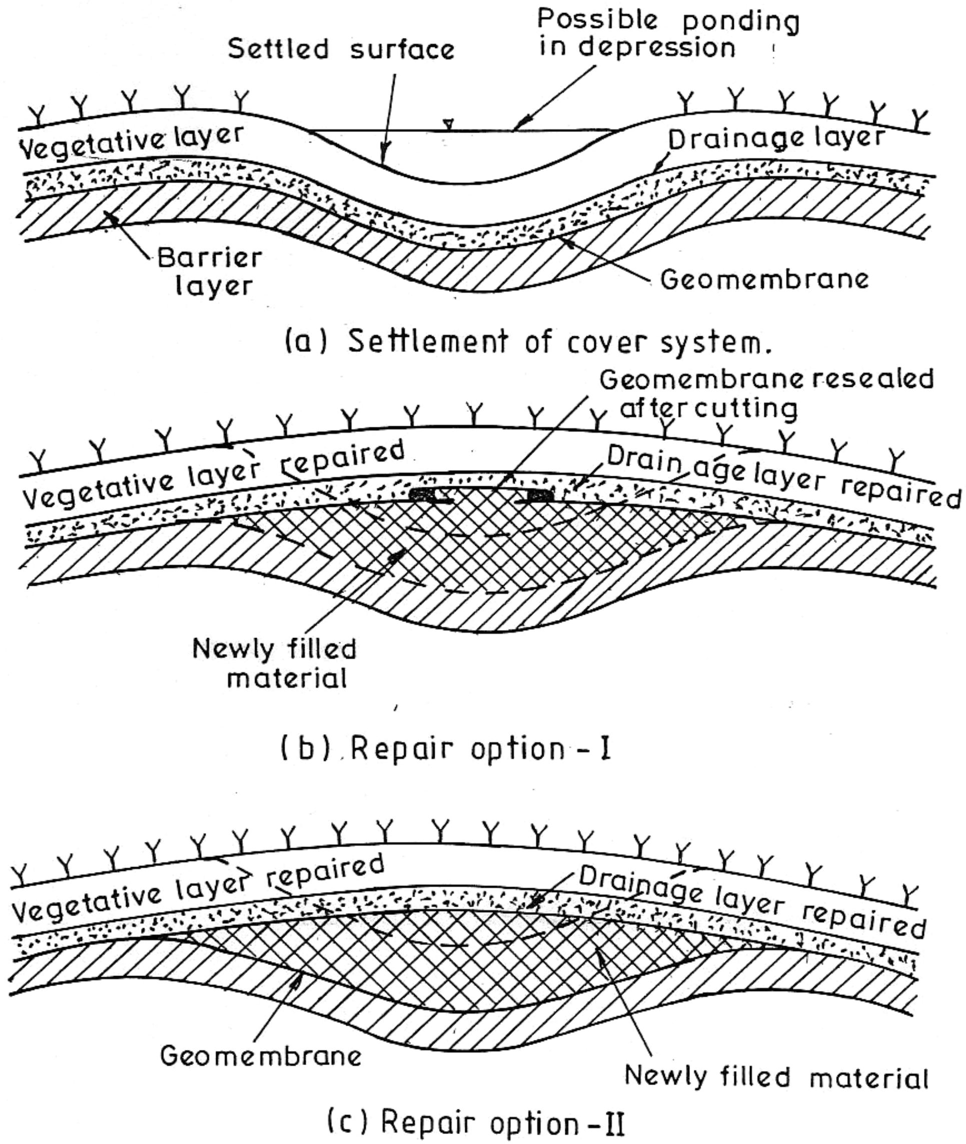


Fig. 8 Repair of cover

Some Lessons Learnt

- Some old waste dumps have heights in the range of 10 to 20m with good potential for gas recovery.
- They have steep side slopes.
- Slopes have to be flattened to ensure stability of covers.
- Composite covers + gas collection (wells with / without suction) can result in efficient methane recovery.
- Cost of covers and cut-offs (upto Rs 2500/- per sqm (USD 50 persq.m)) can be offset by gas collection.

Conclusions

The present study leads to the following conclusions:

- The interfaces between the geomembrane and the clay beneath it or the geotextile above it are the weak locations at which slippage is likely to occur.
- Seepage force parallel to the geomembrane during monsoon as well as horizontal seismic loading during earthquakes causes the factor of safety to reduce significantly.
- Provision of veneer reinforcement in the soil above the geomembrane, and use of textured geomembrane, improves the stability of slope.
- Provision of berms at intervals of low heights also helps in increasing the stability of the cover system.

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6th Int. Congress on Environmental Geotechnics

8 – 12th Nov 2010, New Delhi, India

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Plenary & Keynote Speakers

- **2 Dr. Kerry Rowe**
- Queen's University, Canada
- ***Title of Lecture: Factors affecting the clogging of leachate***
- ***collection systems in MSW landfills***
- **3 Dr. Jean-Pierre Gourc**
- Domaine Universitaire, France
- ***Title of Lecture: The bio-hydro-mechanical behavior of MSW (Municipal***
- ***Solid Waste) and the improvement of landfill environmental sustainability***
- **4 Dr. Mario Manassero**
- Politecnico di Torino, Italy
- ***Title of Lecture: Basic and advanced theories for modeling***
- ***geoenvironmental phenomena***
- **5 Dr. G.E.Blight**
- University of the Witwatersrand, South Africa
- ***Title of Lecture: Combating short & long term water and wind erosion***
- ***from the surfaces of waste storage structures***
- **6 Dr. Antonio Gens**
- Universitat Politecnica de Catalunya, Spain
- ***Title of Lecture: Environmental geotechnics and nuclear waste***
- **7 Dr. Kenichi Soga**
- University of Cambridge, United Kingdom
- ***Title of Lecture: Long-term engineering performance and in-situ***
- ***assessment of cement-bentonite cut-off walls***
- **8 Dr. Stephan Jefferis**

- **Dr. Maria Eugenia Gimenez Boscov**
- Polytechnic School of the University of São Paulo, Brazil
- ***Title of Lecture: Brazilian experience in geo-environmental***
- ***applications of tropical soils***
- **2 Dr. Yunmin Chen**
- Zhejiang University, China
- ***Title of Lecture: Development of leachate head and control of leacharelated***
- ***failures at MSW landfills in humid regions***
- **3 Dr. John Cowland**
- Geosystems Ltd., Hong Kong, China
- ***Title of Lecture: Geomembrane reservoirs for storage of***
- ***hazardous and methane generating liquids***
- **4 Dr. Albert T. Yeung**
- University of Hong Kong, Hong Kong, China
- ***Title of Lecture: New developments in electrochemical***
- ***remediation of contaminated soil***
- **5 Dr. Georg Heerten**
- RWTH Aachen University, Germany
- ***Title of Lecture: The new German landfill directive and environmental***
- ***advantage of using geosynthtics in landfill sealing systems***
- **6 Dr. Takeshi Katsumi**
- Kyoto University, Japan

Thank you