Reduction of Unintentionally Produced Persistent Organic Pollutants (UPOPs) emissions by improving waste management practices at landfills

Landfill Operations – Operational Practices

GEF Project ID: 5558 – Component 2 - Development and Implementation of a Sustainable Management Mechanism for POPs in the Caribbean

11 October 2021

BCRC CARIBBEAN
Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean

UN environment
United Nations Environment Programme

Resources & Waste Advisory Group

gef

STOCKHOLM CONVENTION

UNIDO

Addressing causes and consequences of landfill fires

Building upon the results of the exercise in ”Landfill practices that impact operational resilience” presentation, the factors that triggered, caused and were identified to be the root cause of a fire on the landfill are considered further.

This presentation focusses in on addressing the operational aspects that were identified as causing or triggering a landfill fire, as the main disruptive incident that results in the most substantial emissions of uPOPs from a landfill site.

Grouping causes and consequences

Trigger factors, causes and root causes groups

1. Landfill Operations (directly controllable by the waste management authority)
2. Waste segregation (consumer / producer behaviour and collection operators)
3. Finance / Policy framework (national level)

Consequence chain of events / cascading effects groups

1. Harm to general population (health, safety and environment)
2. Risk to landfill safety and soundness (operational integrity, includes financing operations)
3. Risk to national economic stability and governance

These groups enable us to identify key stakeholders to make responsible and accountable for interventions

FINANCE / POLICY FRAMEWORK

SEGREGATED MANAGEMENT LANDFILL OPERATION

Tyre / white good levy finance not ringfenced for tyre recycling	No resources allocated to recovery or recycling	Unmanaged tyre stockpiles at risk of ignition	Fire on landfill
No management strategy for tyres / white goods			
Increasing number of vehicles and associated waste tyres	No proper management of bulky waste, white good, tyre stockpiles		
Insufficient budget allocated to machinery	Lack of / inappropriate machinery	Insufficient waste compaction and cover	
Unqualified award of equipment contracts	Operators insufficiently trained		
Poor enabling environment to attract investment in alternate waste treatment tech	Insufficient alternatives to landfill		
Waste not segregated at source	Lithium batteries in waste crushed by compactor and ignite waste mass	Flammable material ignites working face	
No site security	Waste pickers active on site	Open burning to recover metals	
No enforced ban on purchasing burnt wire	Recyclers pay more for wire without plastic		
No plan for fire breaks	De-bushing not conducted around landfill site	No fire breaks maintained fire enters landfill / stockpiles	
No tools to cut bush regularly	Fire on neighbouring plot		
Green waste and cardboard bulky and consuming void space	No alternate option for treating green waste and card	Open burning on site as a management practice	

Trigger factors, causes / root causes – LANDFILL OPERATION

Tyre levy finance not ringfenced for tyre recycling	No resources allocated to tyre recycling	Unmanaged tyre stockpiles at risk of ignition	Fire on landfill
No management strategy for tyres	**No proper management of tyre stockpiles**		
Increasing number of vehicles and associated waste tyres			
Insufficient budget allocated to machinery	Lack of / inappropriate machinery	Insufficient waste compaction and cover	
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1

Components of a Sanitary Landfill (recap)

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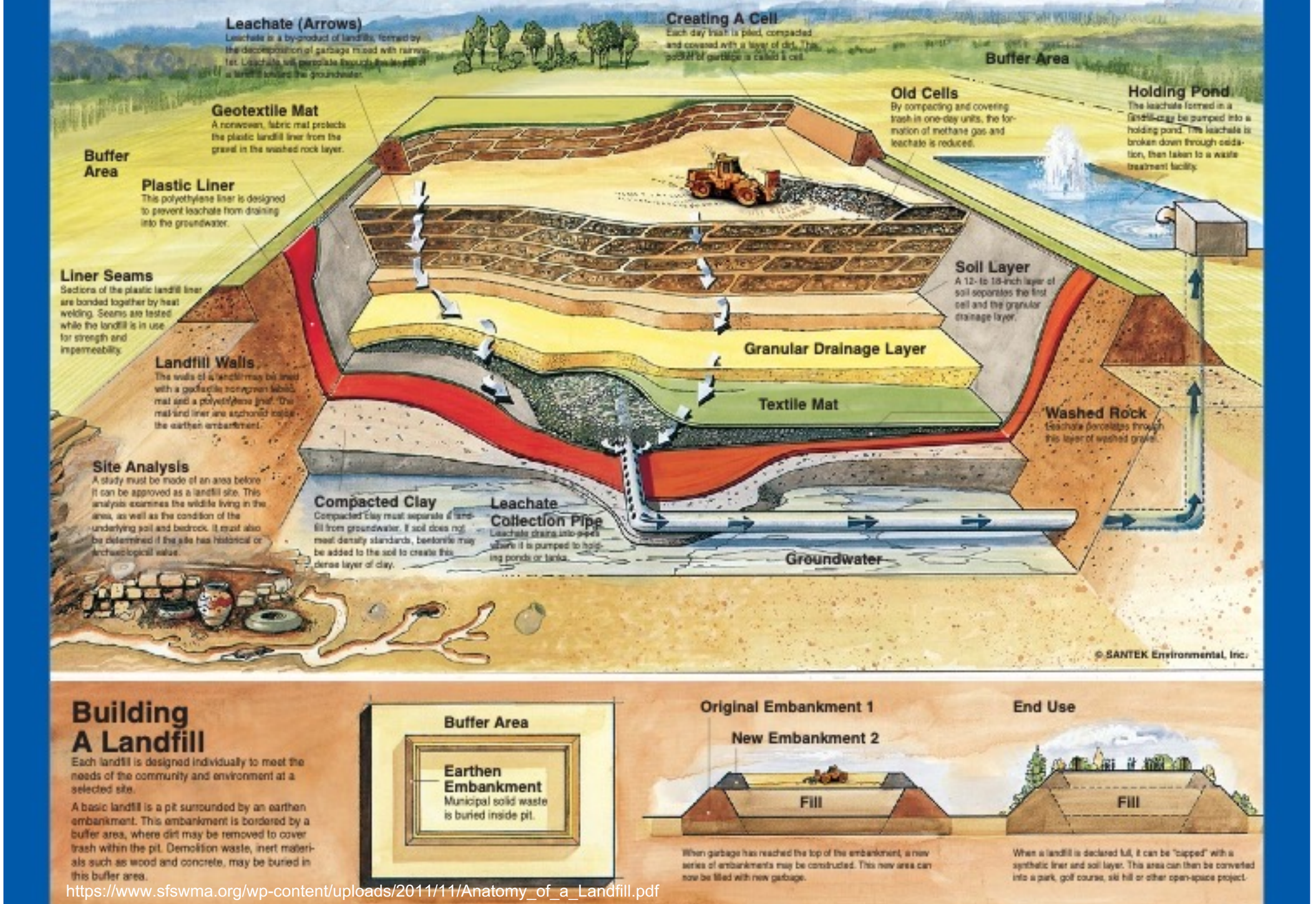

https://www.sfswma.org/wp-content/uploads/2011/11/Anatomy_of_a_Landfill.pdf

UN Habitat Waste Wise Cities - Landfill Control Ladder

The UN Habitat WASTE WISE CITIES TOOL provides a step-by-step guide to assess a city's Municipal Solid Waste Management performance through Sustainable Development Goals (SDG) indicator 11.6.1 monitoring

Within this tool, a guide is provided to classify the control level of landfills, the Landfill Control Ladder (see image). Basic Control is the minimum level of control required to meet the SDG 11.6.1 and offers a minimum level that any disposal site must meet.

Access the UN Habitat Waste Wise Cities Tool (WaCT) Data Portal at:

https://unh.rwm.global

CONTROL LEVEL	Landfill Site
Full Control	• Waste daily covered • Waste compacted • Site fenced and full 24-hour control of access • Properly sited, designed and functional sanitary landfill • Leachate containment and treatment (naturally consolidated clay on the site or constructed liner) • Landfill gas collection and flaring and/or utilization • Site staffed; • Post closure plan • Weighing and recording conducted • Protection of workers' health and safety
Improved Control	• Waste periodically covered • Waste compacted • Site fenced and control of access • Leachate containment and treatment • Landfill gas collection (depending on landfill technology) • Site staffed • Weighing and recording conducted • Protection of workers' health and safety
Basic Control	• Some use of cover • Waste compacted • Sufficient equipment for compaction • Site fenced and control of access • No fire/smoke existence • Site staffed • Weighing and recording conducted • The slope of the landfill is stable, landslides not possible • Protection of workers' health and safety
Limited Control	• No cover • Some compaction • Some equipment for compaction • Some level of access control/fencing • No leachate control • Some fire/smoke existence • Site staffed • Weighing and recording conducted • The slope of the landfill is unstable with high possibility of a landslide
No Control	• No cover • No compaction • No/ limited equipment • No fencing • No leachate control • Fire/smoke existence • No staff • The slope of the landfill is unstable with high possibility of a landslide

Without proper Operation and Maintenance, a Landfill is just a dumpsite

Without proper Operation and Maintenance, a Landfill is just a dumpsite

More than just engineering

CATEGORY	REQUIREMENT
• **Security**	• Physical boundary surrounding the site and supervised access control 24/7
• **Water and leachate control**	• Site engineering preventing surface and groundwater ingress into the landfill • Functioning leachate containment liner, collection and management
• **Slope stabilization**	• Slopes stabilized, including erosion control, to mitigate risk of collapse
• **Waste handling, compaction and cover**	• Waste deposited in clearly defined operational areas with strict management control • Waste layered and compacted promptly • Daily and intermediate cover applied
• **Fire control**	• Zero occurrence of burning of waste within the landfill site
• **Landfill gas management**	• Landfill gas controlled with utilization where practicable
• **Staffing**	• Site staffed full-time with professionally qualified personnel
• **Recording**	• Functional weighbridge in use with recording waste quantities by waste types
• **Environment Health and Safety (EHS)_**	• EHS measures implemented in accordance with professional risk assessment and operating plan • Showering and sanitary facilities • Environmental monitoring system in place with annual reporting capability
• **Site planning**	• Site development and operational filling plan in place • Post closure plan in place

Operation Management priorities

1. **Leachate, surface and rain/stormwater management**
   - Minimise leachate and ensure leachate collection and treatment operational.
   - Surface water drainage in place around site perimeter and along all access and internal tracks isolating it from waste.
2. **Containment and compaction**
   - Tipping pad and Working face defined with layering and compaction (including machine availability, fuel and maintenance)
3. **Cover - daily and intermediate**
4. **Slope stability and erosion control**
5. **Site monitoring and data interpretation to inform decision making**

2

Waste inspection and acceptance

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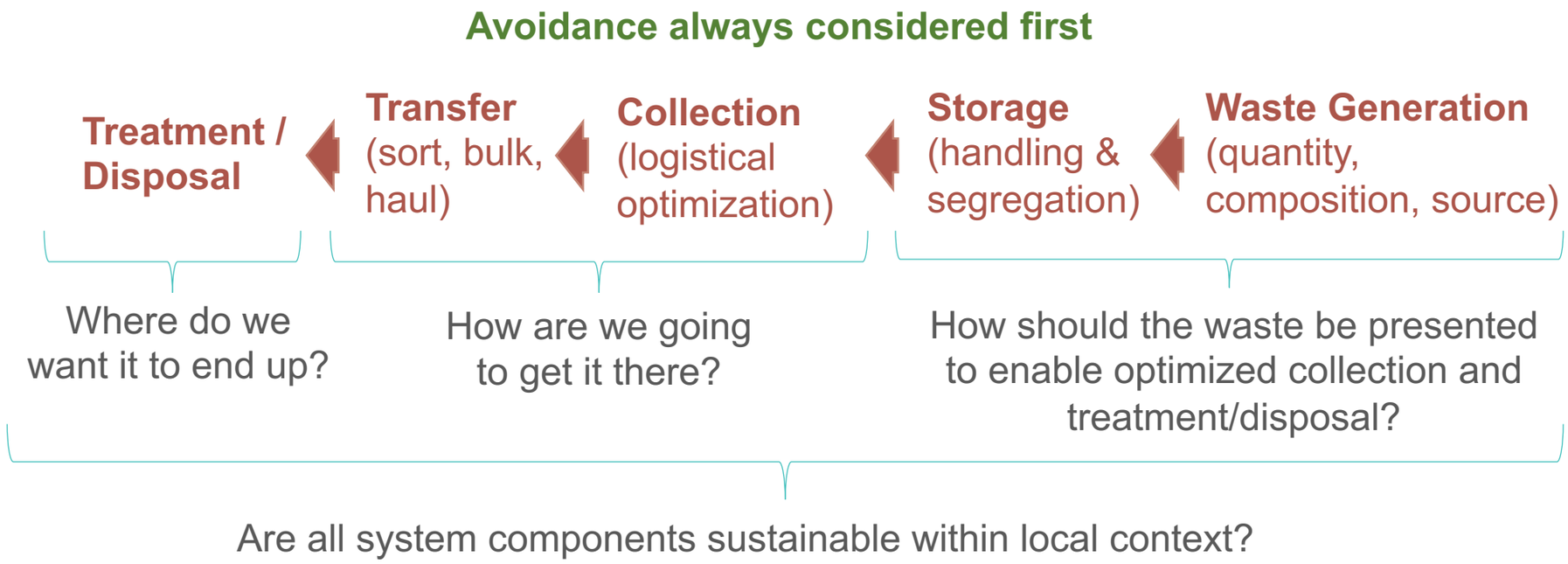
Focus Waste Streams

1. Municipal Solid Waste / Household Waste – **Sanitary Cell**
2. Industrial, Commercial and Institutional (ICI) Waste – **Sanitary Cell**
3. Construction and Demolition Waste – **Bays – Wood / Rubble / Plastics**
4. Parks and Gardens (green waste) – **Compost**
5. Recyclable Packaging – **Recycle (bale and send to Antigua?)**
6. Tyres – **Bays - Tyres**
7. End-of-Life Vehicles (ELV) – **Depollute - Bays**
8. Waste Electrical and Electronic Equipment – **Recycle / Bays – White Goods / HWISF**
9. Used Lead Acid Batteries (ULABS) – **Pallet and send for Recycling**
10. Agricultural pesticide residues and used containers - **HWISF**
11. Laboratory Chemicals (hazardous) - **HWISF**
12. Oils and petroleum Contaminated Wastes - **HWISF**
13. Medical Waste – **Autoclave / controlled incineration**

Practical Approaches

Planning the system in reverse, starting with the end goal, can have many benefits – especially when you know the target waste stream.



- **Applicable** Technically (using the Best Available Technology);
- **Affordable** Financially;
- **Acceptable** Environmentally and socially (following Best Environmental Practice);
- **Achievable** Legally;
- **Appropriate** Institutionally (can the institutions administer and enforce system)

Waste inspection and acceptance

Acceptance criteria Categories

Accepted wastes

General waste, always allowed

Difficult wastes

Always accepted but require specific handling/segregation on site.

Special wastes

Sometimes accepted if no alternate exists, but requires specific handling

Prohibited wastes

Never allowed on the landfill

Accepted Waste

The following general wastes are accepted in a landfill:

- Domestic solid waste, as collected by city or private vehicles on a regular basis;
- Acceptable commercial and industrial waste regularly collected by contractors;
- Garden refuse (i.e., green waste or yard waste) that may or may not be collected separately to municipal waste; and
- Inert waste (i.e., construction and demolition debris including concrete, timber, masonry, bricks, etc.)

Difficult Waste

These are wastes that are accepted at a landfill but require special treatment or diversion to ensure that the best compaction or disposal is achieved. Some wastes, such as car bodies, drums, and white goods, may be better recycled depending on operational preferences. This waste class does not include hazardous or dangerous wastes, but includes the following:

- Tyres – **Difficult (divert to stockpile / use in engineering purposes / shredder)**
- Mattresses – **Shred using tyre shredder? Stockpile in appropriate segregation bay?**
- White goods (fridges, freezers, or stoves), - **remove hazardous components and divert to broker, stockpile in appropriate segregation bay or container, non-hazardous to landfill**
- Vehicle bodies, - **divert to broker / baler**
- Drums - **divert to broker / baler**
- Condemned food and other bulk food waste – **Compost (in-vessel)**

Special Waste

These are other wastes that may be accepted on-site but will have to be decided on a case-by-case basis. This may include some hazardous and dangerous wastes:

- Asbestos;
- Medical waste, including “sharps;”
- Dead animals;
- Pathogenic wastes;
- Dry sludge, such as treatment plant sludge;
- Low-level radioactive waste;
- Liquid waste, including paints and thinners;
- Toxic substances, such as acids and biocides (pesticides and herbicides); and
- Contaminated soil.

Main option to excavate area in non-operational zone and cover with adequate waste and cover material to prevent exposure to rain and other elements.

For all difficult and special waste streams

- Management plan required, and regularly communicated and inspected by all staff
- All Landfill staff must know how to inspect waste and identify the different classifications and know what to do with them (even for prohibited wastes).

Treatment on site

e.g. shredding, composting, etc.

Storage

e.g. designated interim hazardous waste storage facility, defined small piles separated by fire breaks, baling and containerization.

Controlled placement in landfill cell

e.g. shredded tyres as cover material, encapsulation of chemicals within concrete (place in barrel and fill with concrete before disposing in landfill), etc.

Prohibited Waste

Items that are always unacceptable in a landfill include:

- Hot loads, greater than 500°C in temperature;
- Pressure cylinders (e.g., condemned gas cylinders and fire extinguishers);
- Recyclables, except to the recycling area (e.g., green waste, bulk metals, or reusable demolition waste);
- Large volumes of liquid waste;
- Radioactive waste;
- Large containers which cannot be crushed;
- Dangerous goods, such as reactive chemicals, explosives including signal flares,
- Batteries, particularly ULABs and LiPo

Suitable Operator Models

- Tyre recycling
- End-of-Life Vehicles
- Hazardous wastes (interim storage and export)
- Waste Electrical and Electronic Equipment
- Used oil
- Beverage Containers and other Packaging recovery
- Green garden waste
- Food waste

All suitable for Extended Producer Responsibility (EPR) scheme

Can be managed locally by private sector – if right enabling environment established

Managing stockpiles to mitigate fire risk

Fire Prevention Objectives

- Minimise the likelihood of a fire happening
- Aim for a fire to be extinguished within 4 hours – EVERYONE TO HAVE FIRE EMERGENCY CONTACT NUMBER ON PHONES ON SITE AT ALL TIME
- Minimise the spread of fire within the site and to neighbouring sites

Fire Prevention Basics

- Implement effective fire prevention and site procedures to minimise the risk of fire occurring
- Limiting the size of waste material stockpiles as far as is practicable
- Maintaining adequate clearance between stockpiles and other infrastructure
- Configuring stockpiles in a way that ensures access for firefighting and maximises its effectiveness
- Protection of human health and the environment in the event of a fire.

Manage stockpiles with adequate bunding

Stockpile bays with fire walls (WEEE, White goods, Tyres)

Special Wastes

1. Agricultural pesticide residues and used containers - **Special**
2. Laboratory Chemicals (hazardous) - **Special**
3. Oils and petroleum Contaminated Wastes - **Special**
4. Medical Waste – **Special**

Will be discussed in more detail in Module 4 to be held on 12th October

Prohibited Wastes

Recyclable Packaging – **Prohibited (if recycling market exists)**

Used Lead Acid Batteries (ULABS) - **Prohibited**

3

Cell Structure and Operations

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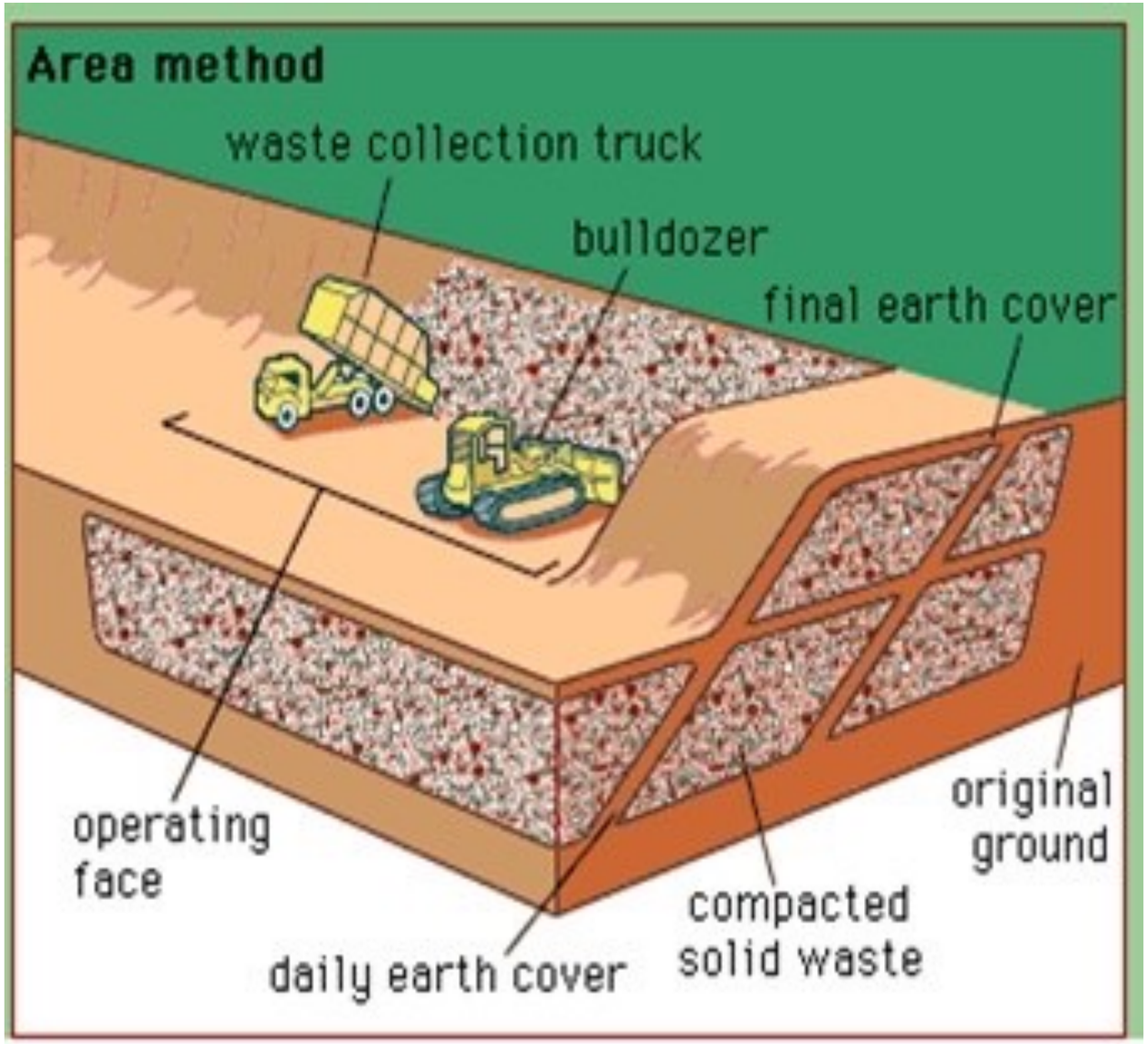
Cell structure and operations

- Layout and cell development
  - Cell layout and fill plan
  - Tipping area (defined, organized and contained)
- Compaction
  - Mixing waste loads on tipping pad
  - Spreading and compaction
- Adequacy of machine and operator
  - Type and Size of Machinery
- Cover materials
  - Cover Types
    - Daily, intermediate and final
  - Application quantities, timing and techniques
- Operations Health and Safety
  - Site security
  - PPE

Basic concept - cell structure and control

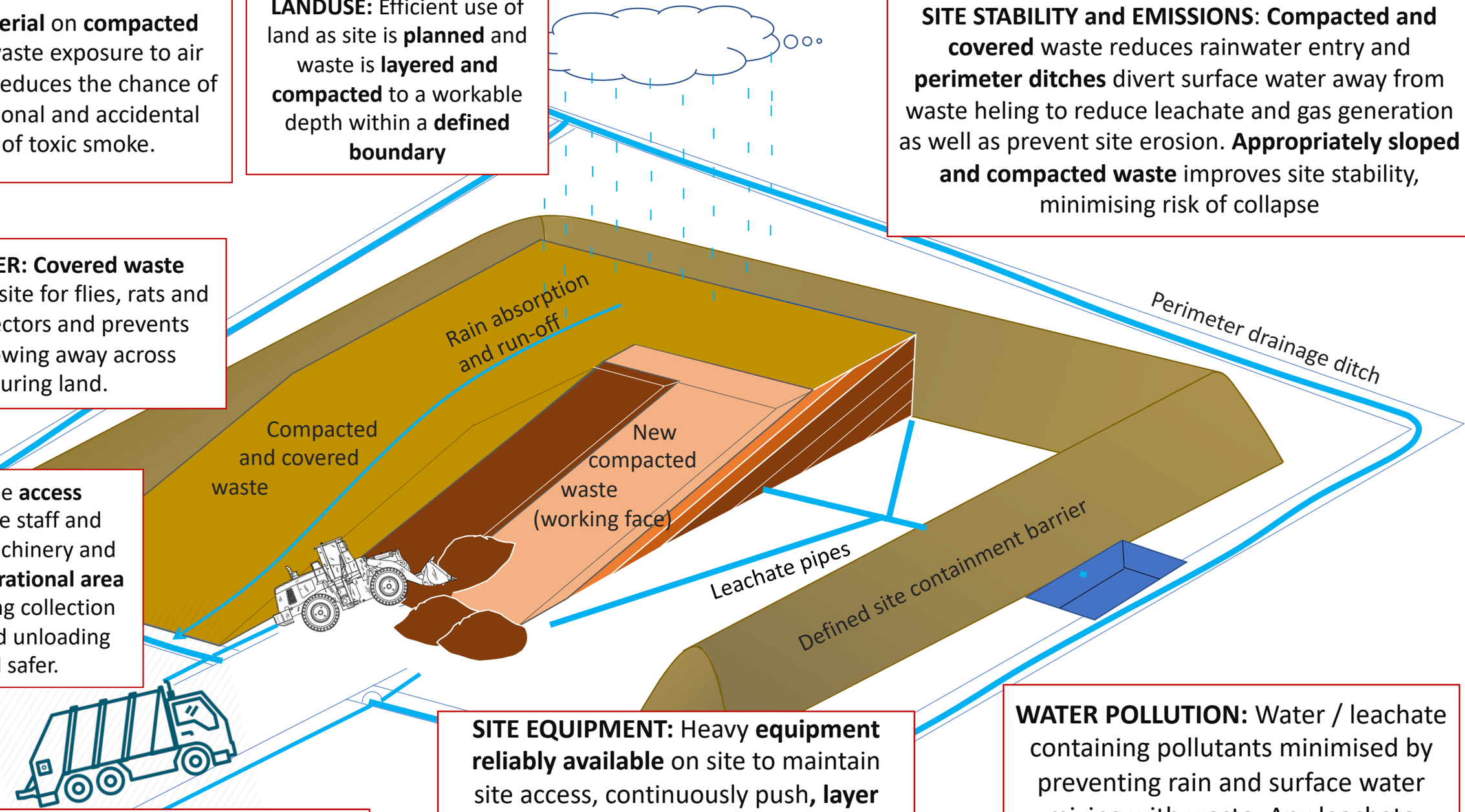


FIRE: Cover material on **compacted waste** reduces waste exposure to air and dramatically reduces the chance of fire, both intentional and accidental limiting risk of toxic smoke.

LANDUSE: Efficient use of land as site is **planned** and waste is **layered and compacted** to a workable depth within a **defined boundary**

SITE STABILITY and EMISSIONS: **Compacted and covered** waste reduces rainwater entry and **perimeter ditches** divert surface water away from waste heling to reduce leachate and gas generation as well as prevent site erosion. **Appropriately sloped and compacted waste** improves site stability, minimising risk of collapse

PESTS and LITTER: Covered waste reduces breeding site for flies, rats and other disease vectors and prevents waste from blowing away across neighbouring land.



ACCESS: Vehicle **access monitored** by site staff and **maintained** by machinery and with a **specific operational area for disposal** making collection vehicle access and unloading efficient and safer.

WASTE ACCEPTANCE: Waste separation at source and loads inspected, hazardous and problematic materials banned from disposal

SITE EQUIPMENT: Heavy **equipment reliably available** on site to maintain site access, continuously push**, layer and compact** incoming waste in **defined area**, apply **cover material**, and maintain site

WATER POLLUTION: Water / leachate containing pollutants minimised by preventing rain and surface water mixing with waste. Any leachate collected through pipes to leachate treatment.

Layout and site development Plan

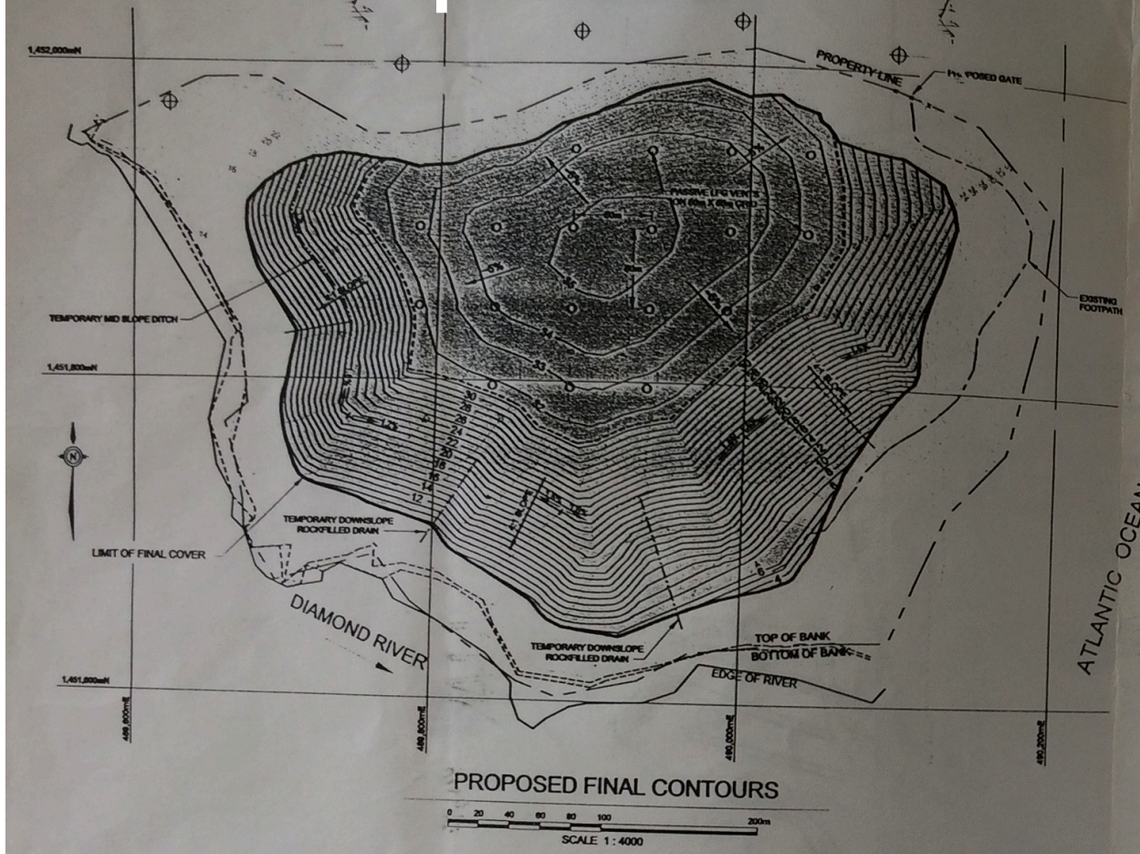
- There is a need to have a site plan with all infrastructure and waste fill, development and storage areas clearly planned and reviewed on a monthly and redrawn regularly (annually) or when new infrastructure is installed.

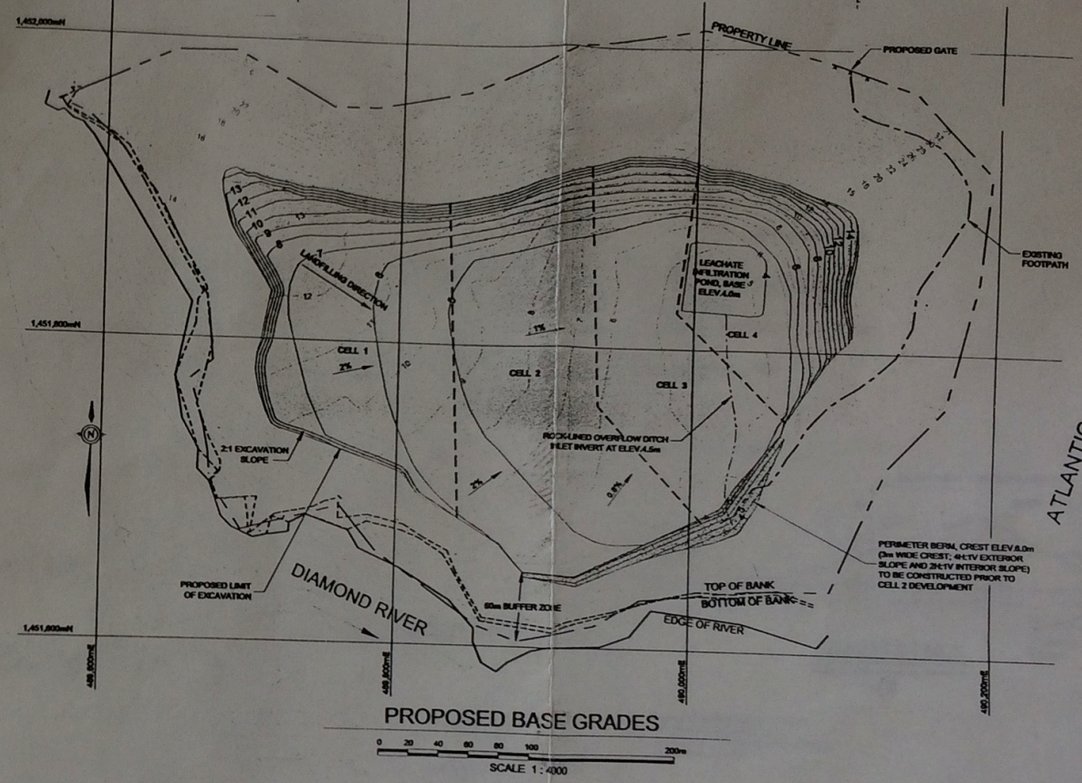
- The rate of fill must be monitored quarterly to enable revision of predicted future void space / storage area needs and associated investment needs in future site.

- Site supervisors and Machine operators must be briefed and be given performance standards based on design and held accountable to that.

Diamond Landfill – Fill Plan

Example from Saint Vincent and the Grenadines





LEGEND

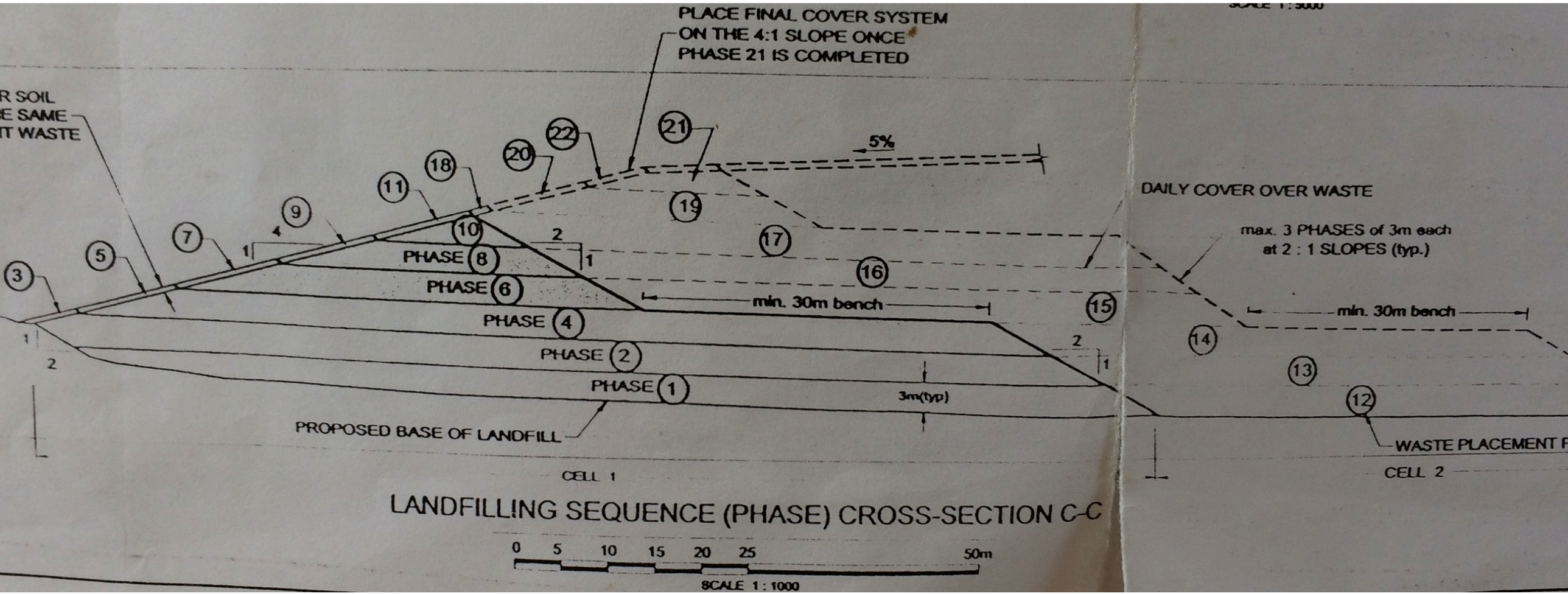
TP-1D TEST PIT LOCATION IN PLAN

BH0830D BOREHOLE LOCATION IN PLAN

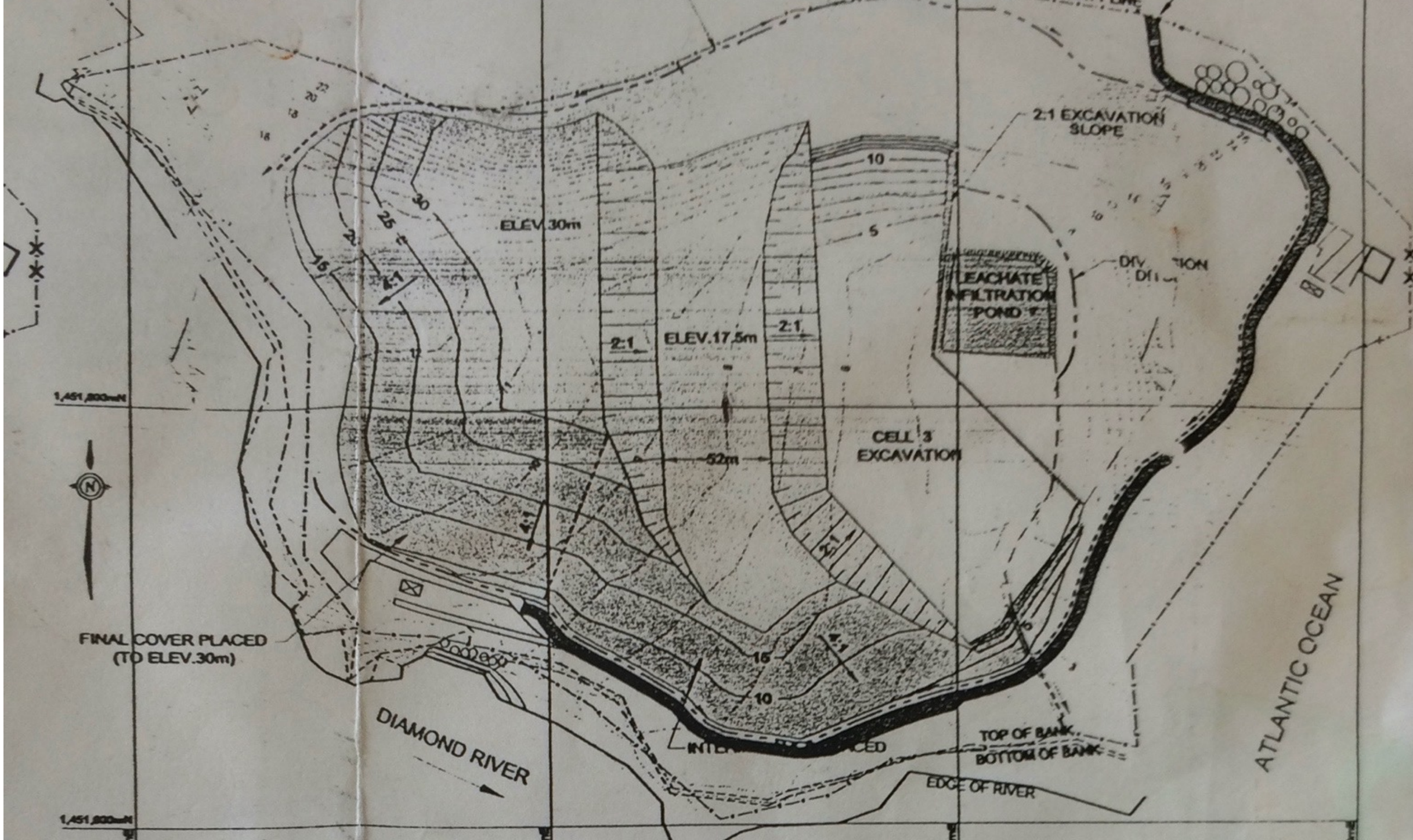
PROPOSED LFG MONITORING PROBES

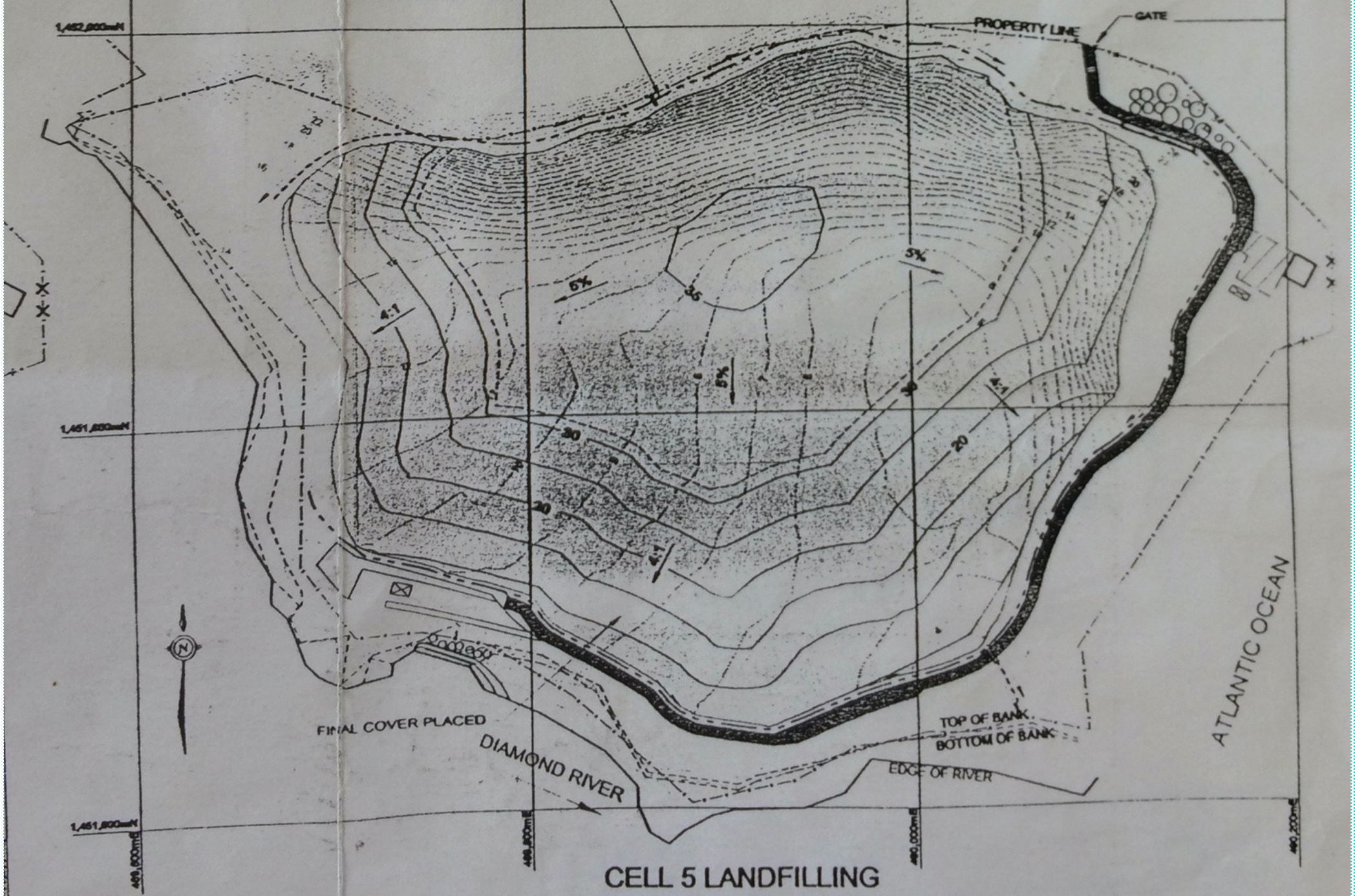
PROPOSED PASSIVE LFG VENTS IN PLAN

NO.	DATE	REVISION	BY	CHK	ENG	APP
D	AUG. 28/98	FINAL DRAFT	-	-	-	
C	JULY 23/98	ISSUED AS FINAL DESIGN	MHW	DPA	JMAC	
B	MAY 15/98	CONCEPTUAL DESIGN FOR PRESENTATION TO C.W.S.A.	MHW	DPA	JMAC	
A	APR.21/98	CONCEPTUAL DESIGN FOR REVIEW BY C.W.S.A.	MHW	DPA	JMAC	



LANDFILLING SEQUENCE (PHASE) CROSS-SECTION C-C


2:1 EXCAVATION SLOPE
ELEV.30m
ELEV.17.5m
2:1
10
5
52m
LEACHATE INFILTRATION POND 1
CELL 3 EXCAVATION
FINAL COVER PLACED (TO ELEV.30m)
DIAMOND RIVER
TOP OF BANK
BOTTOM OF BANK
EDGE OF RIVER
ATLANTIC OCEAN
1,451,800mN



CELL 5 LANDFILLING

YEAR 16.5 to 17.5

Ensure proper slopes and covering

Site stability is ensured by ensuring waste is well compacted in thin layers with no slope becoming too steep.

General rule, all side slopes should be no steeper than 1:3 grade, being 1 metre vertical to 3 metres horizontal. Benching or terracing landfill sides at intervals no greater than ever 10 metres vertical is also good practice.

All slopes should be graded with adequate provisions provided to enable rainwater to run off site without eroding any slopes.

Panchang Bedena Sanitary Landfill - Malaysia

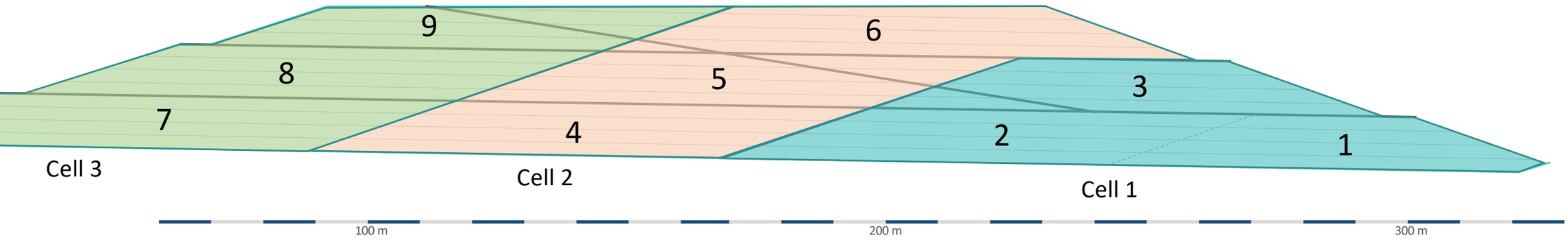
Panchang Bedena Sanitary Landfill - Malaysia

Alternate Cover Material

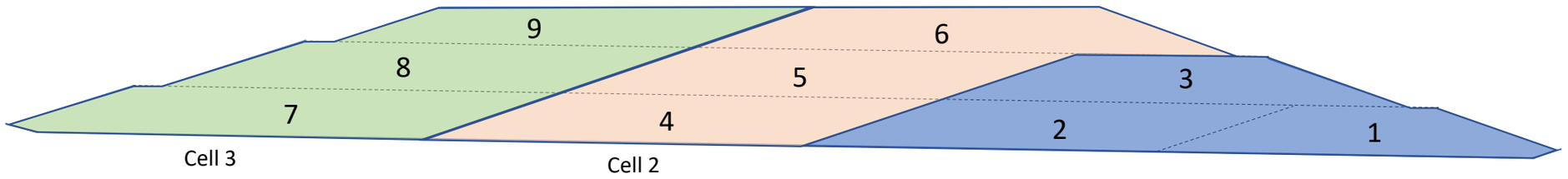
https://www.envirocoversystem.com/products/extended-alternative-daily-cover/

Fill sequence by cell

$C_1 - C_3$



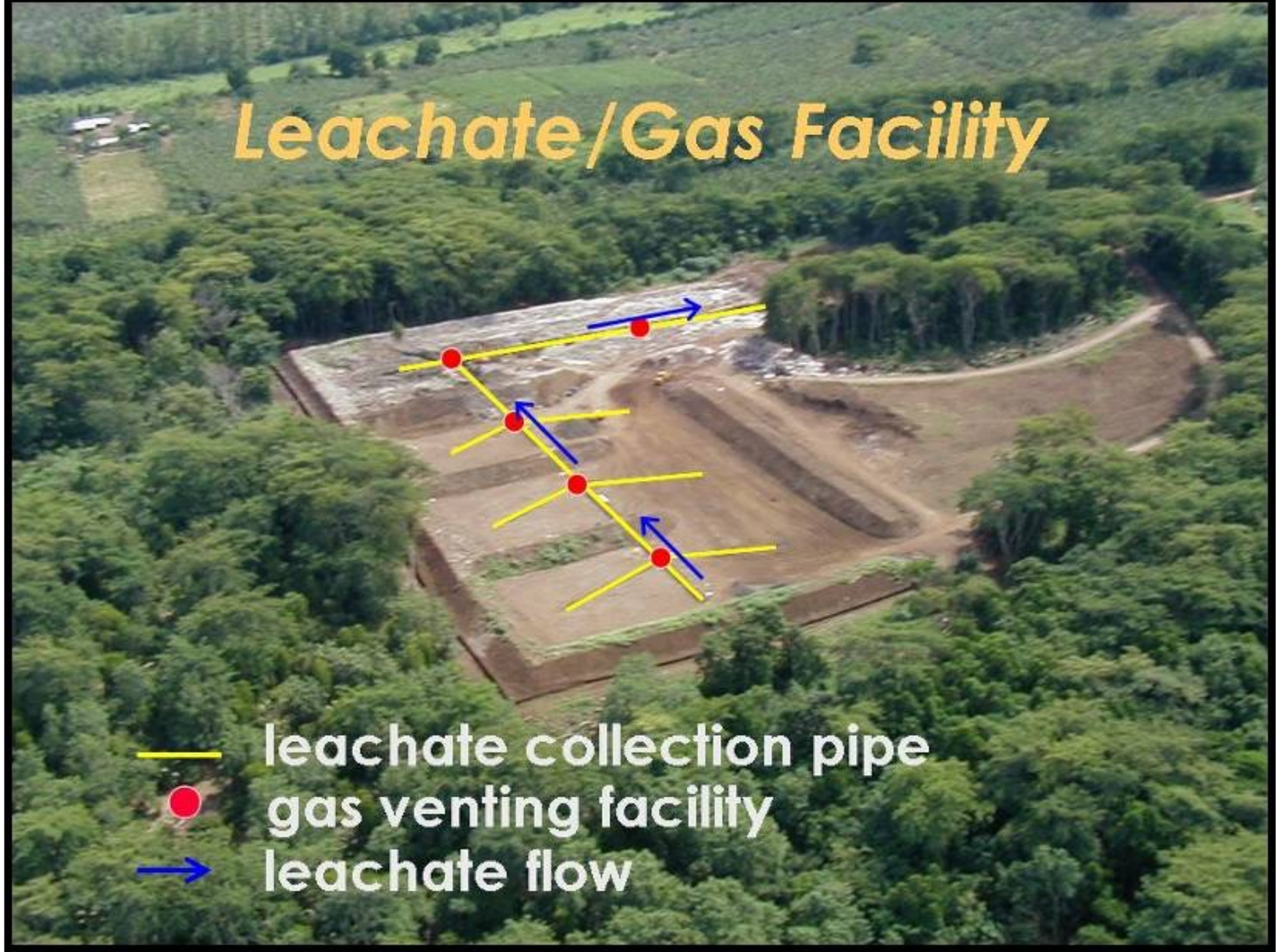
$C_1 - C_3$

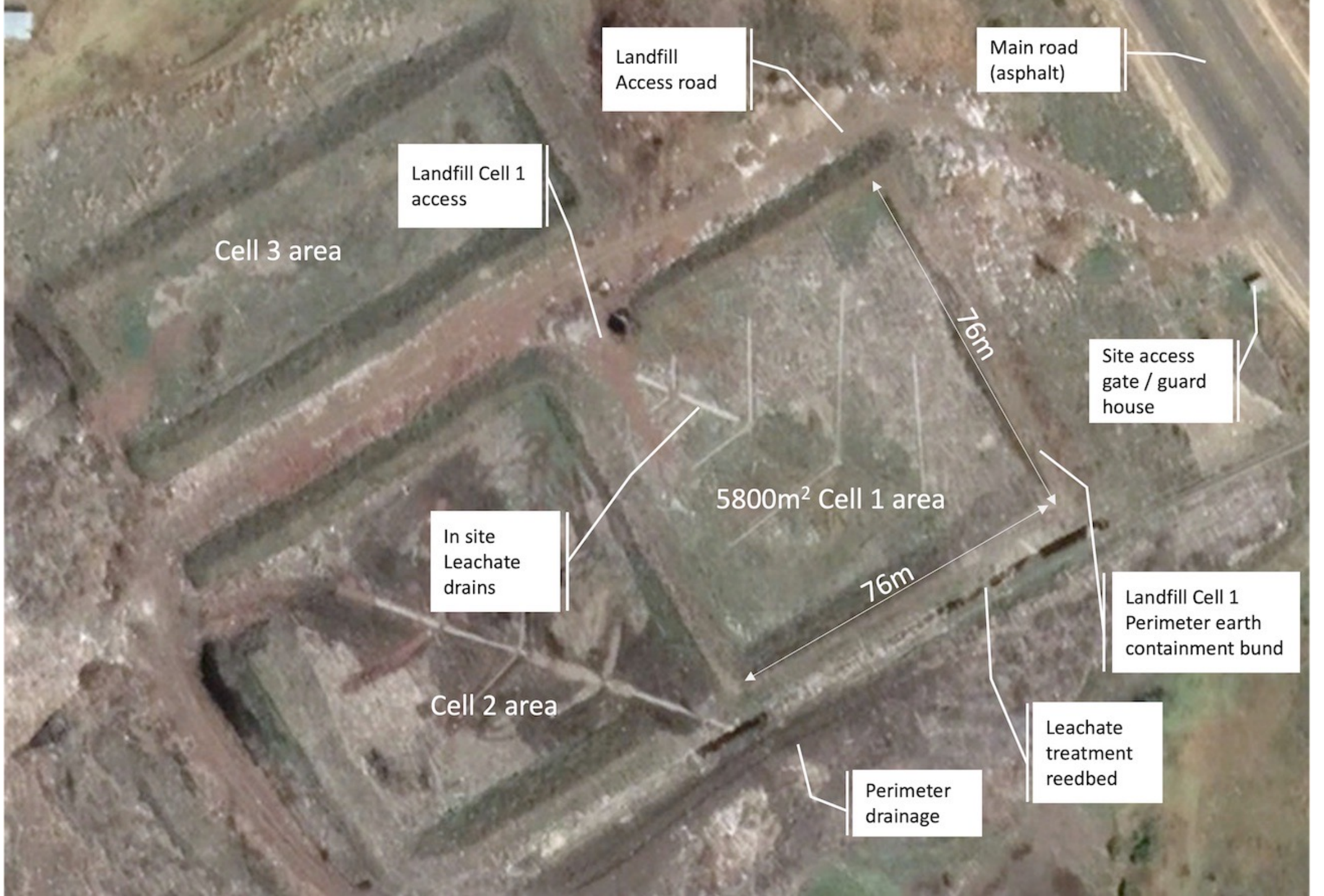


Gas recovery on geomembrane covered site

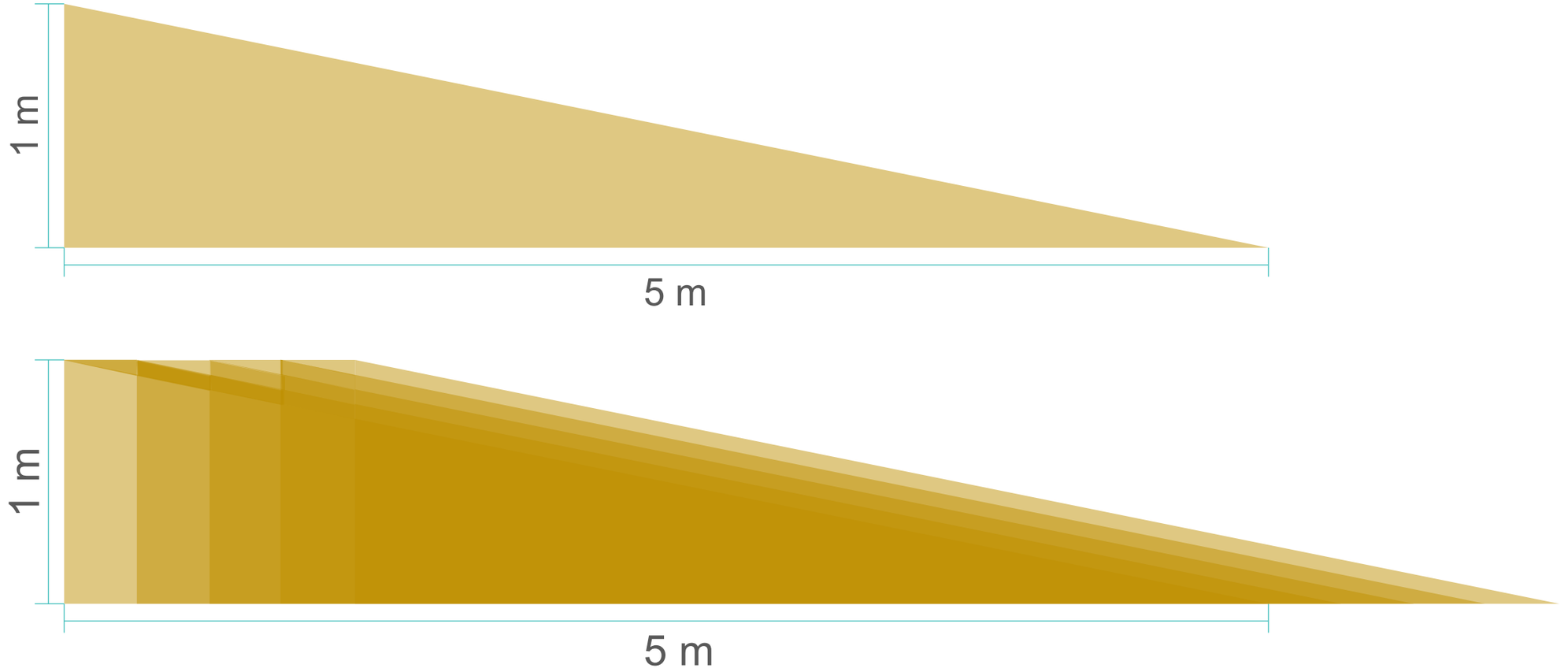
Passive Gas vents

Passive Gas vents


Leachate/Gas Facility
leachate collection pipe
gas venting facility
leachate flow

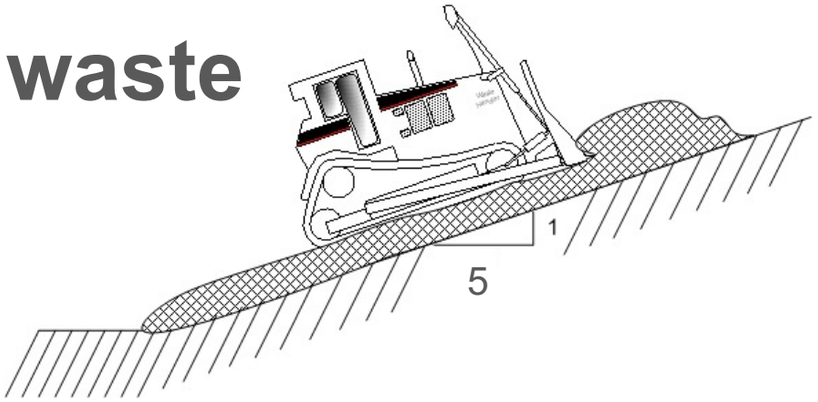

Landfill Access road
Main road (asphalt)
Landfill Cell 1 access
Cell 3 area
76m
Site access gate / guard house
5800m² Cell 1 area
In site Leachate drains
76m
Landfill Cell 1 Perimeter earth containment bund
Cell 2 area
Leachate treatment reedbed
Perimeter drainage

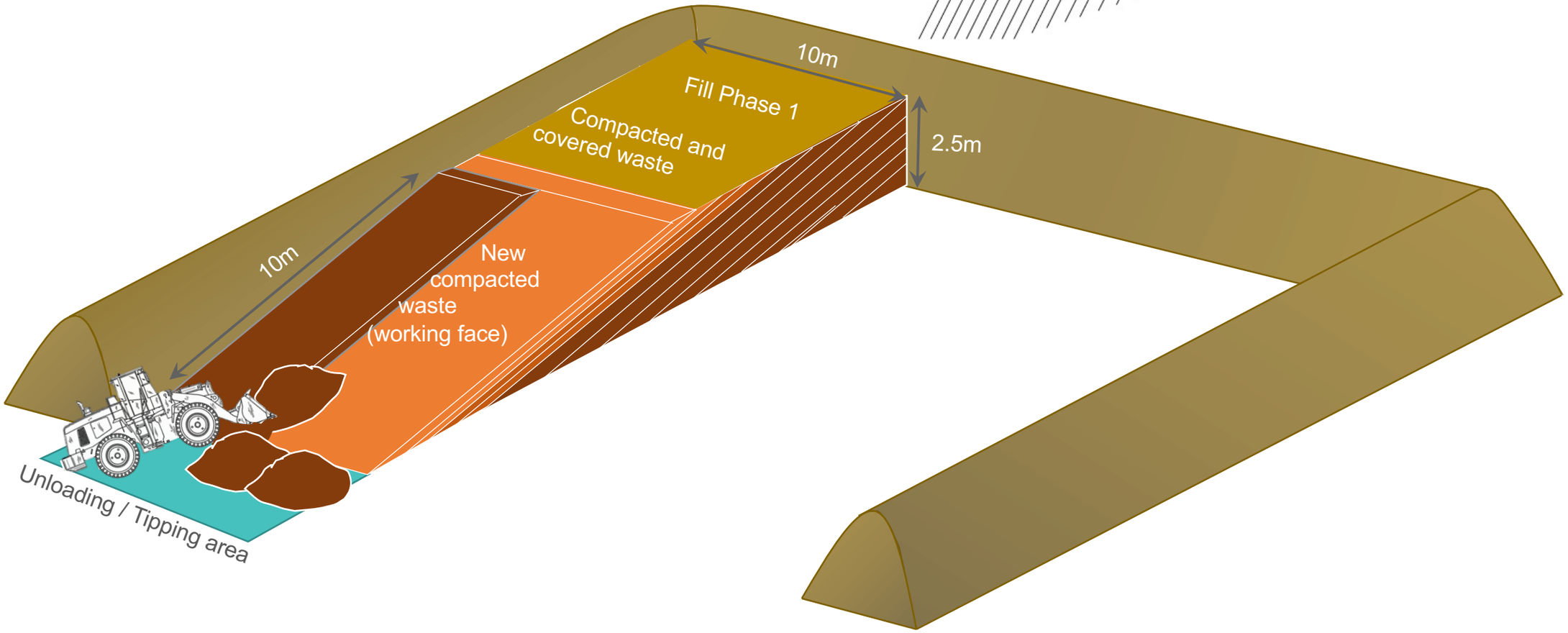
1:5 slope (between 1:3 and 1:10)

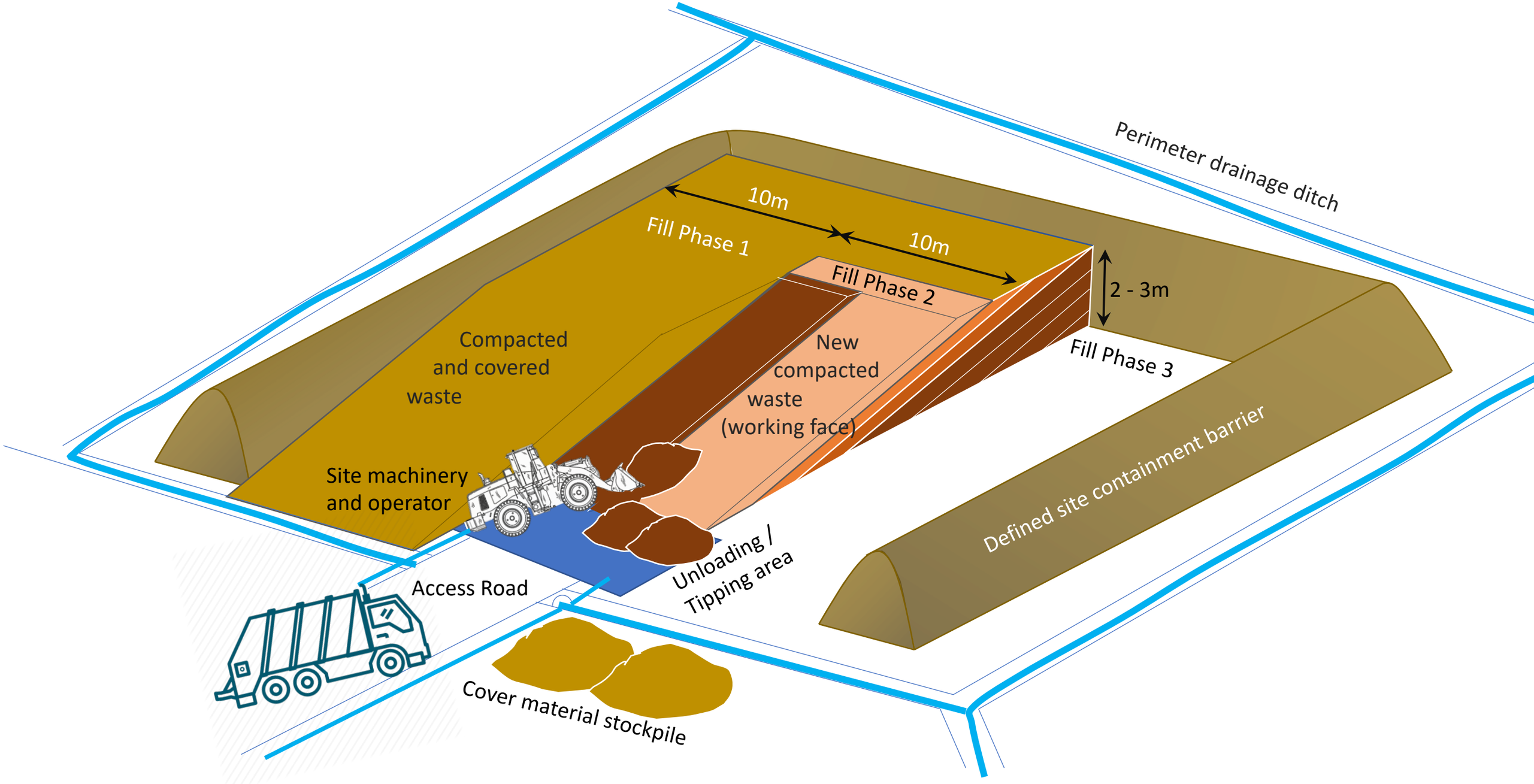


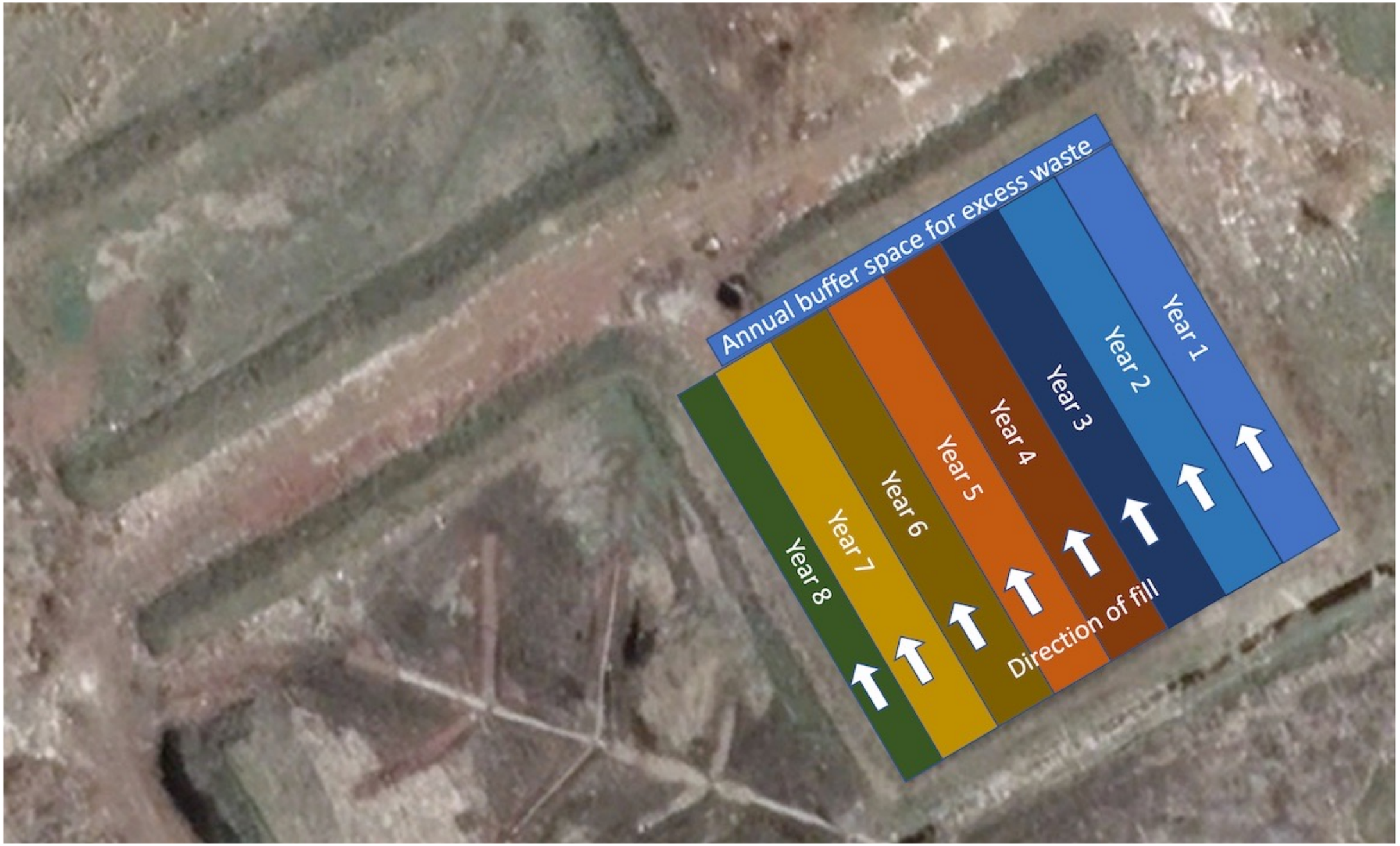
Spreading and Layering daily waste

(maximum 15cm thick layers)



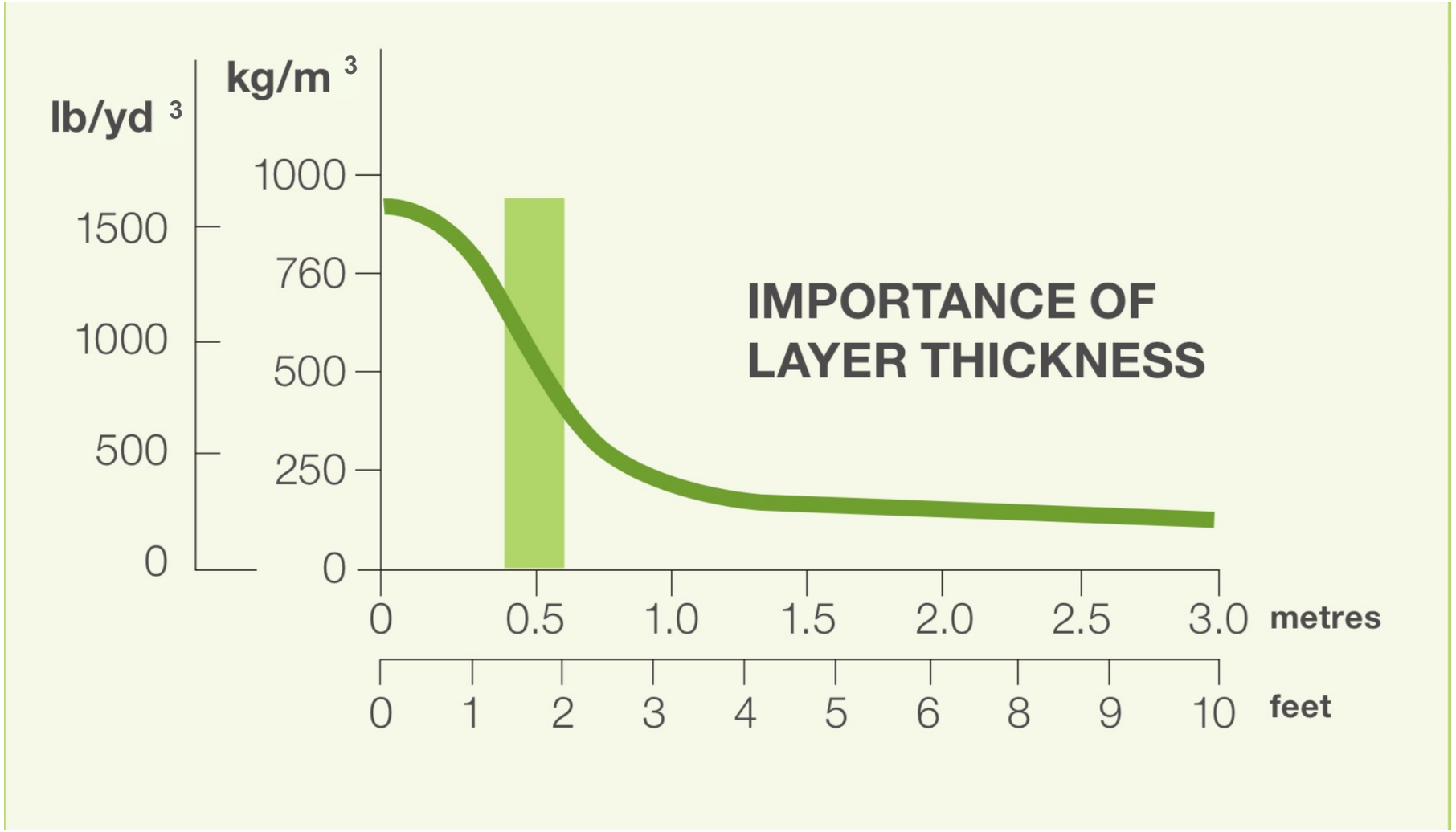



Perimeter drainage ditch
10m
10m
Fill Phase 1
Fill Phase 2
Fill Phase 3
2 - 3m
Compacted
and covered
waste
New
compacted
waste
(working face)
Site machinery
and operator
Defined site containment barrier
Unloading /
Tipping area
Access Road
Cover material stockpile


Annual buffer space for excess waste
Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Year 7
Year 8
Direction of fill

Impact of laps in management / equipment

Optimum Compaction and Waste Layer Thickness



Source: ISWA Landfill Operational Guidelines (3rd edition)

Efficient management of working area

Efficient machine operation is essential. All too often machine operators are not trained, or do not adhere to efficient operating practices.

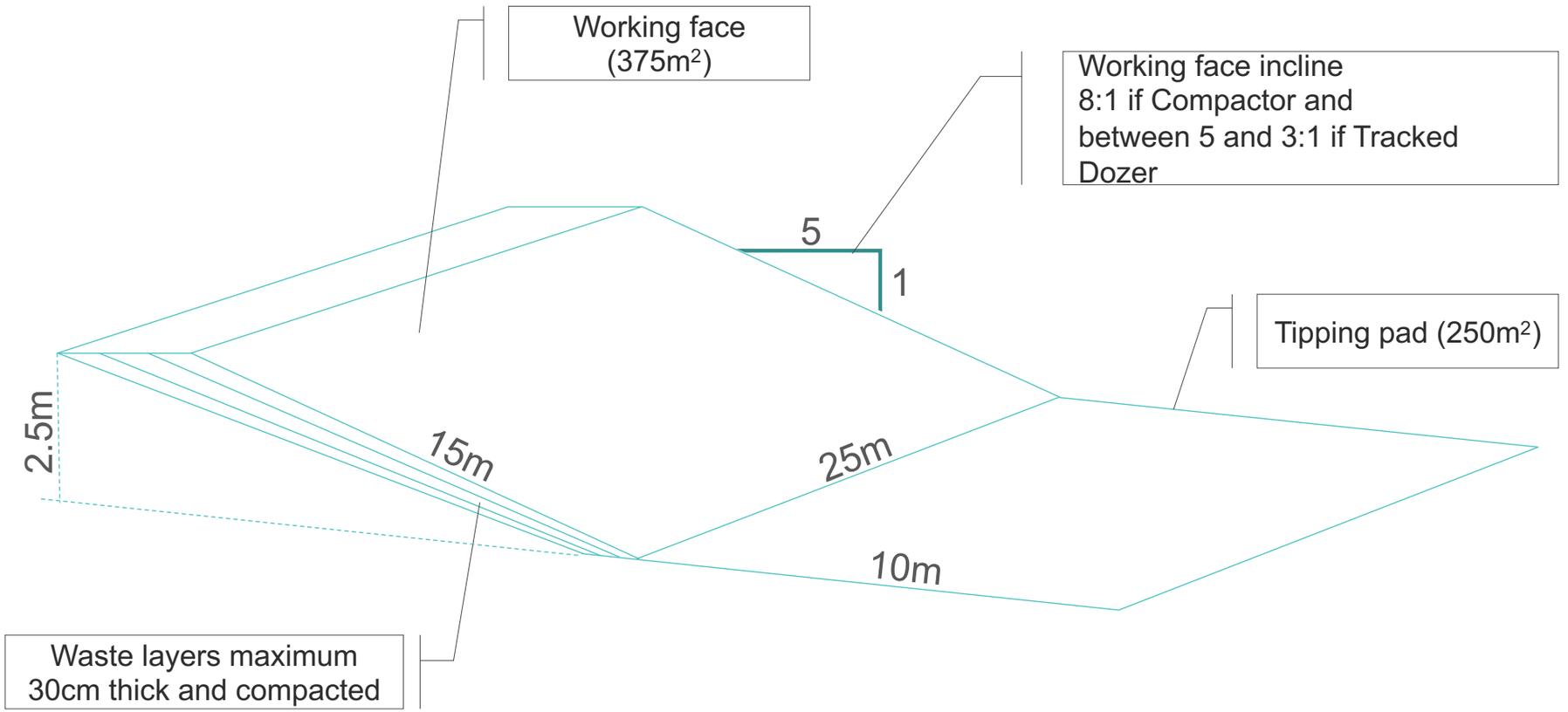
Introduction to working face operations https://youtu.be/h_4u_1q27VY

Example of inefficient working face operations https://youtu.be/Kv4OfdyMLnc

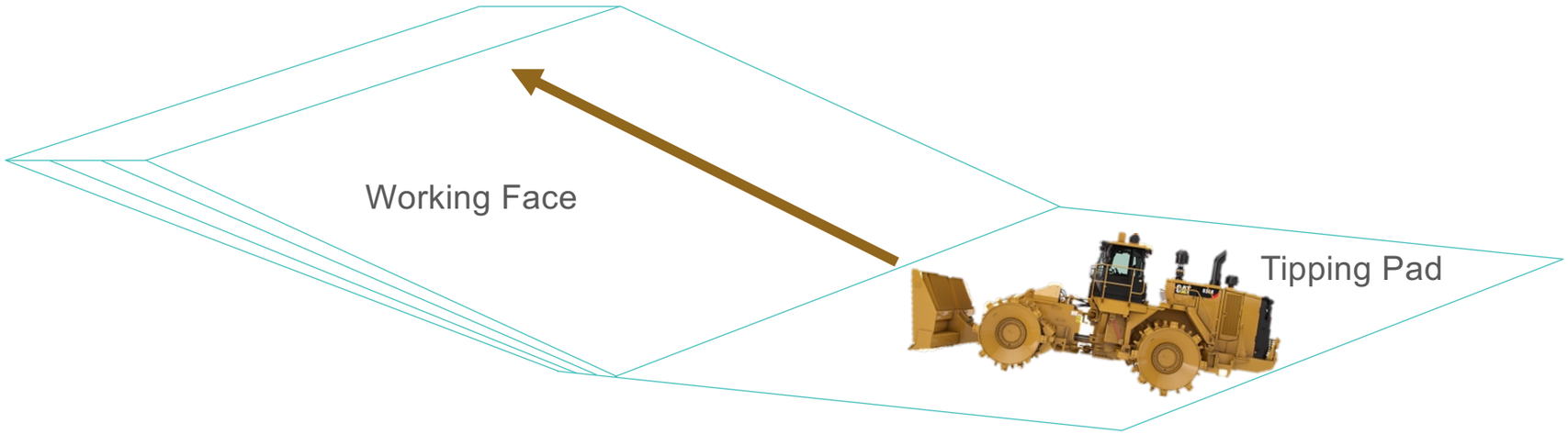
Example of efficient working face operations https://youtu.be/HKHUReULBm0

Daily cell – working face and tipping pad

Guideline dimensions

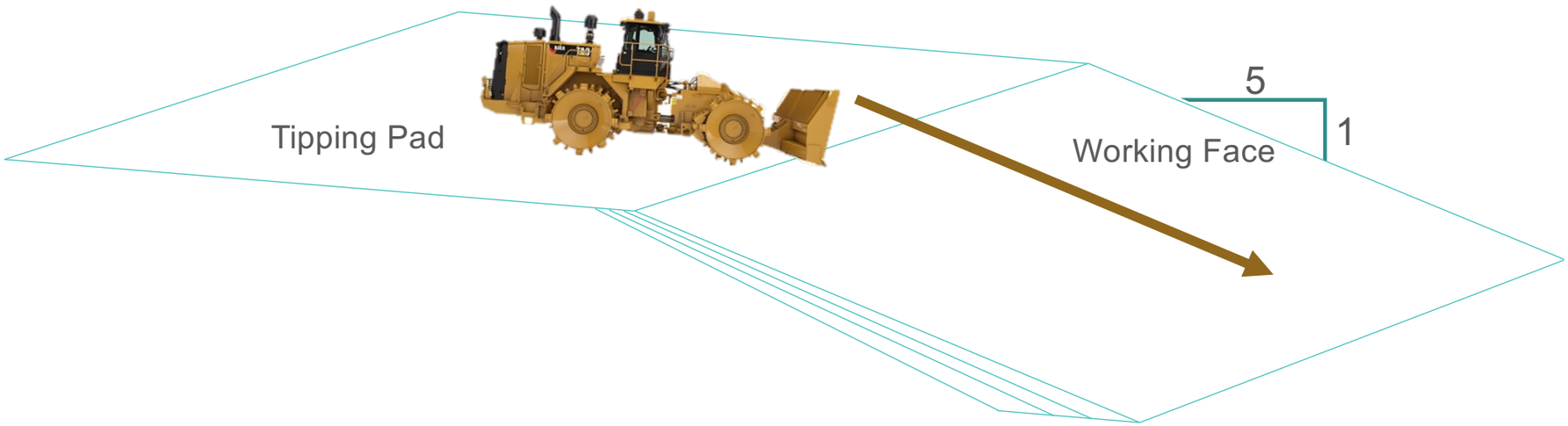


Daily cell – working face and tipping pad



Daily cell – working face and tipping pad

Guideline set-up when wet weather



Area Markers – Guides for compactor

Working face management example

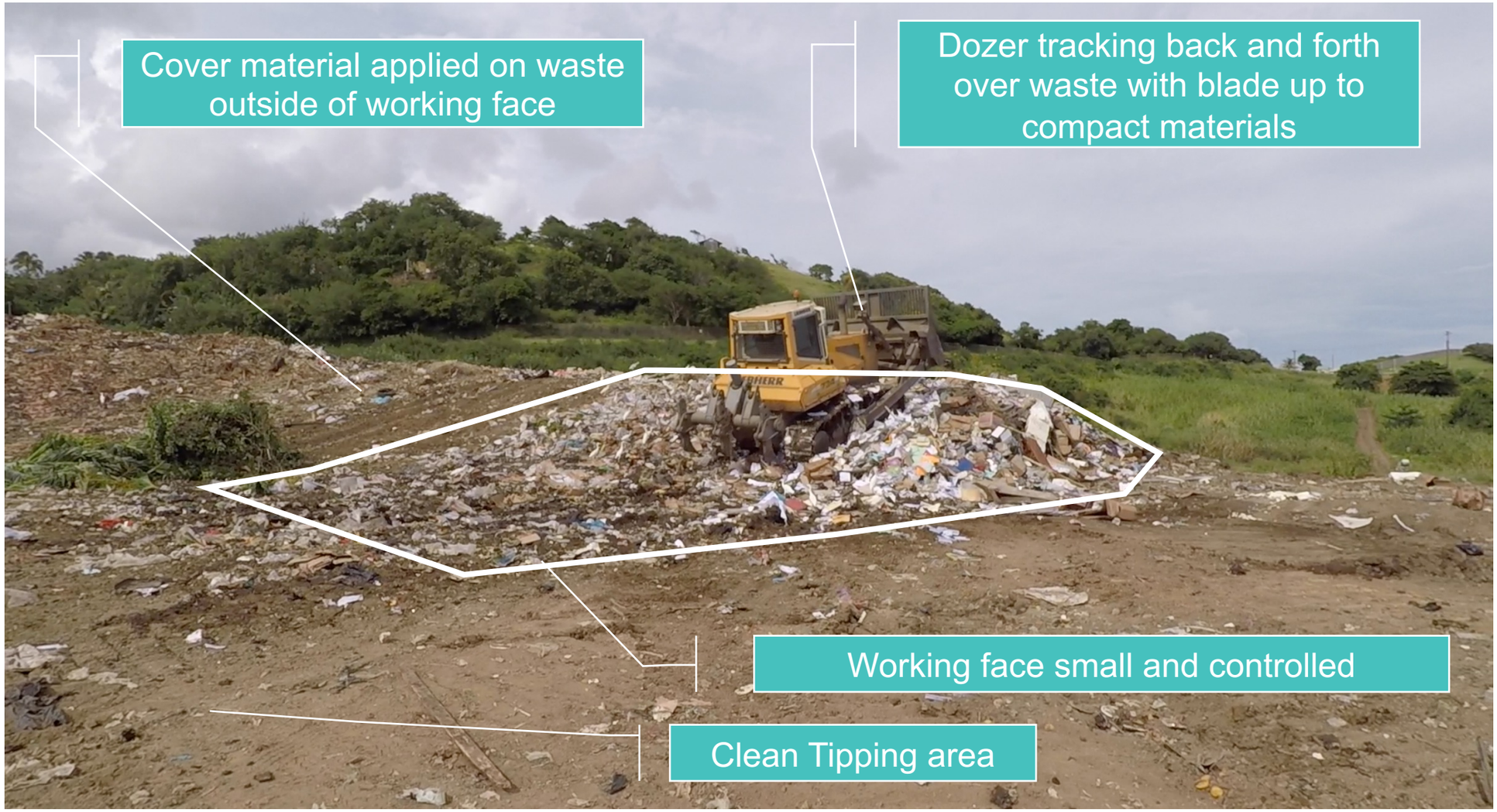
Diamond Landfill – Saint Vincent

Working face management example

Diamond Landfill – Saint Vincent

Working face management example

Diamond Landfill – Saint Vincent



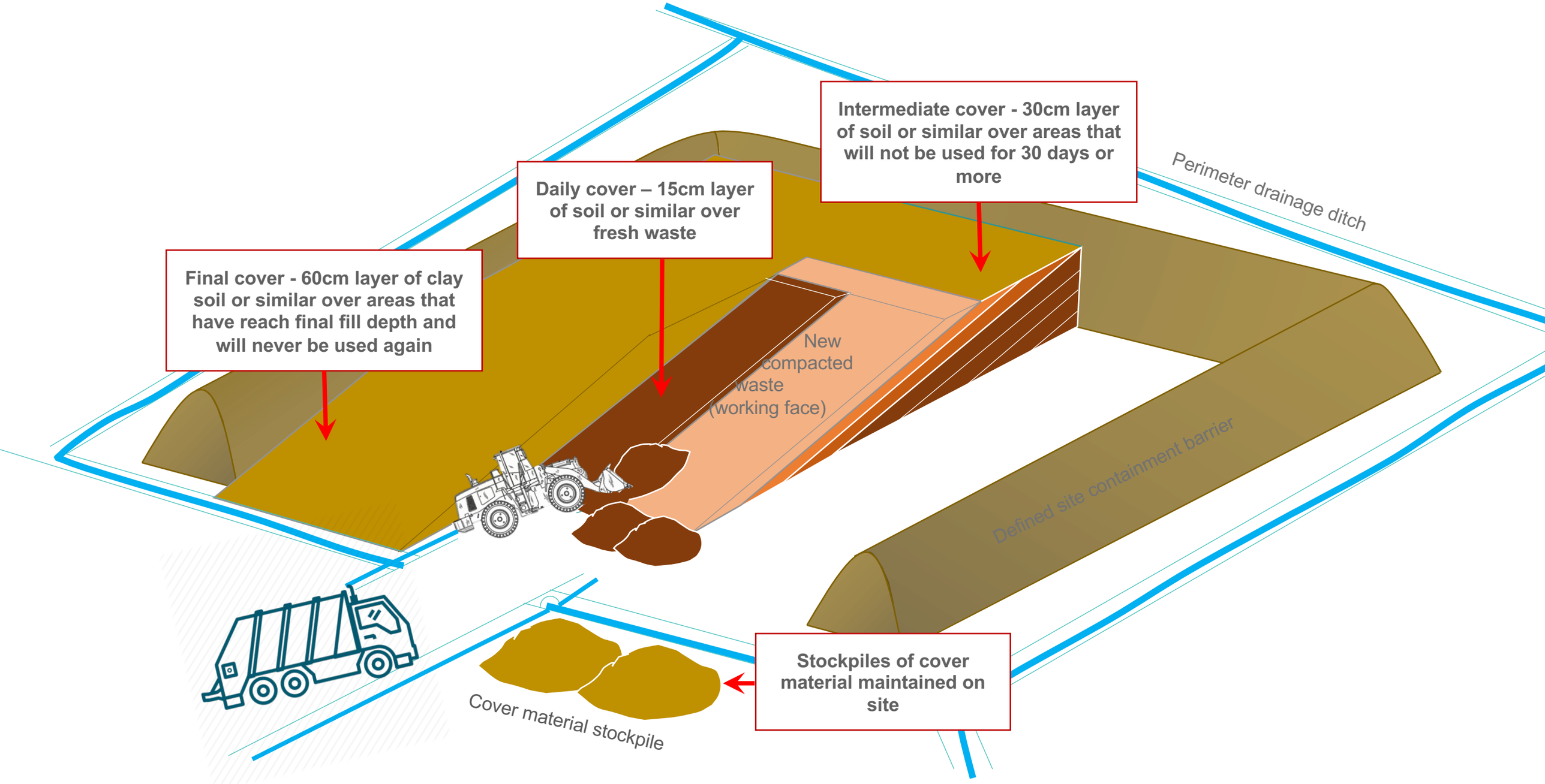
Landfill Needs

- Permanent manager and machine needed:
  - Privatise – Requires strong contract administration and payment terms
  - PPP – Requires strong contract administration and payment terms
  - Public – Requires significant oversight and organisation
- Permanent Machine - repair and maintain existing track loader (ideal machine for needs)? Lease O&M to private operator?
- Site supervisor? Permanent staff who is trained and accountable for proper operations (either direct implementation or supervise contract)?
- Use Sanitary cell for mix low bulk municipal and commercial waste
- Establish bays to temporary accumulate segregated bulky and difficult wastes prior to shredding – this enhances homogenous waste streams and reduces fire risk and risk of fire spreading rapidly.

5

Cover materials

Resources & Waste
Advisory Group


Intermediate cover - 30cm layer of soil or similar over areas that will not be used for 30 days or more
Daily cover – 15cm layer of soil or similar over fresh waste
Final cover - 60cm layer of clay soil or similar over areas that have reach final fill depth and will never be used again
Perimeter drainage ditch
New compacted waste (working face)
Defined site containment barrier
Stockpiles of cover material maintained on site
Cover material stockpile

Daily cover

- Minimise windblown-litter
- Control odours
- Prevent birds from scavenging
- Prevent unauthorised scavenging by humans
- Prevent infestation by flies and vermin
- Reduce the risk of fire
- Assist define the working face for each day and provide a pleasing appearance
- Shed surface water and minimise contamination of runoff generating potential leachate out of the landfill
- Assist in oxidising methane releases

Rainfall, leachate and cover material

Month	Millimeters	Days
January	110	14
February	90	10
March	90	9
April	70	9
May	125	11
June	205	15
July	210	18
August	255	20
September	225	19
October	205	19
November	205	18
December	175	16
Year	1965	178

Diamond

Landfill mass area: 43,000 m^2

Rainfall on waste: 1.9m / year

= 81,700 m^3 / year

Leachate = Rainfall, less evapotranspiration, plus decomposition

30 – 60 cm Cover material absorbs significant quantities of water and prevents it from entering waste and producing leachate. Ensuring cover material depth during rainy season decreases leachate generation.

Types of daily cover materials

Inert	Waste Derived	Artificial / Synthetic
Free draining soils	Paper pulp	Synthetic foams
Non draining soils	Pulped paper	Geotextile matting
Contaminated soils	Shredded wood	Plastic film
Foundry sand	Shredded tyres	Synthetic mesh
Colliery waste	Shredded plastics	Hessian fabric
Quarry waste	Recycling process waste	Tarpaulins
Ash	Shredded green waste	
River silts	Pulverised household waste	
	Compost	

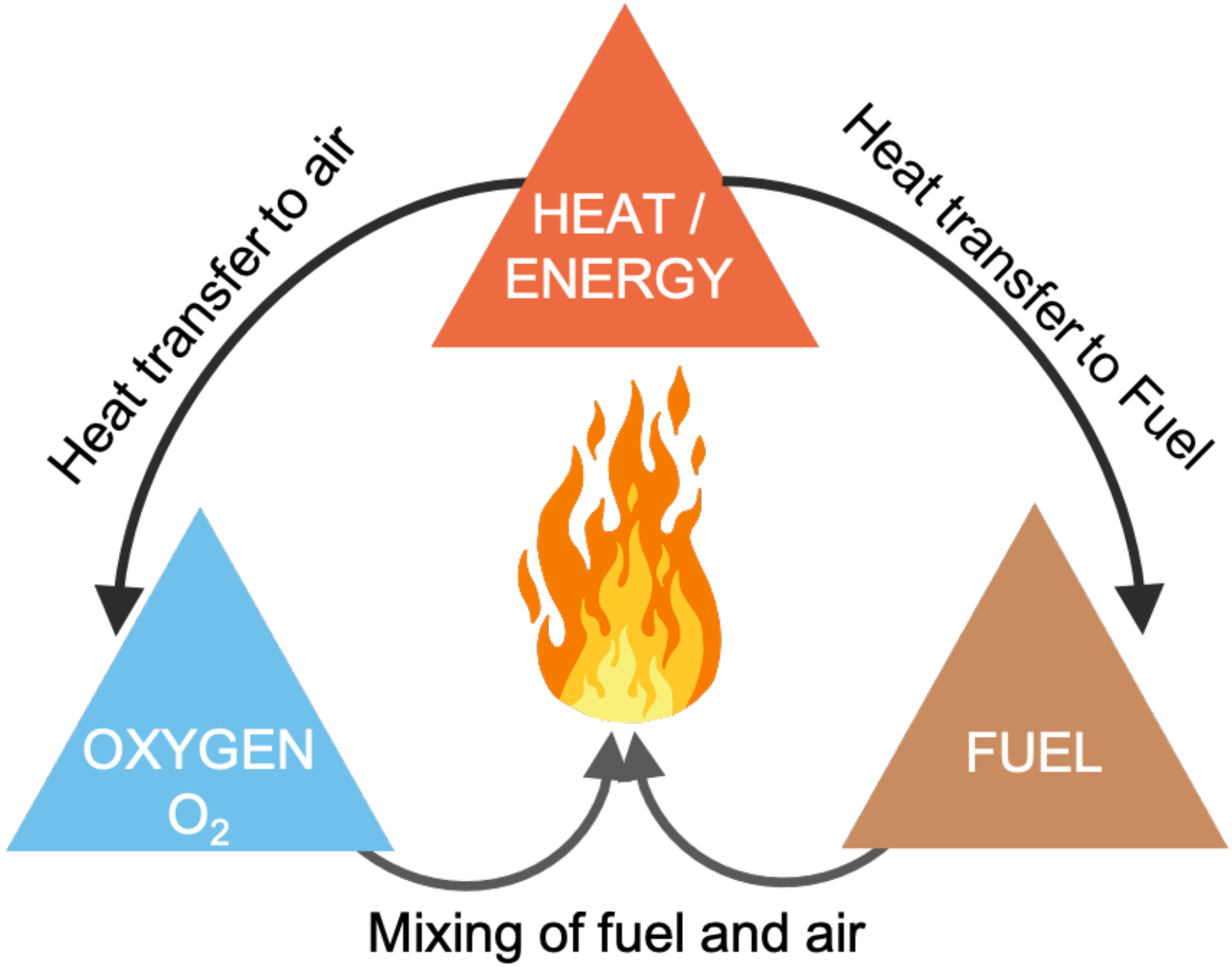
Source: ISWA Landfill Operational Guidelines (3rd edition)

6

Fire control/ contingency plan

Resources & Waste
Advisory Group

Fire Triangle – The needs of a fire



Fire prevention and management

Fires should be minimised at landfill sites as burning rubbish can generate poisonous gases and be an environmental and health risk. The type of control measures typically considered includes:

- Regular soil cover to minimise risk of fires
- Developing a fire management plan including maintenance of an effective fire break around the perimeter of the site, and,
- Developing and regularly (minimum annually) rehearsing emergency procedures for minor and major fires, including soil cover, water spray, excavation of trench, etc. along with other relevant stakeholders

Fire control action / contingency plan

Developing a fire management plan including maintenance of an effective fire break around the perimeter of the site,
Develop and regularly (minimum annually) rehearse emergency procedures for minor and major fires, including soil cover, water spray, excavation of trench, etc. along with other relevant stakeholders

- Defensive Planning
  - Proper compaction and cover materials
  - Properly sized, spaced and bunded stockpiles
  - Bulldozers / earth movers on standby
  - Hazardous / low flashpoint wastes diversion
  - Regular Maintenance checks on equipment and vehicles
  - Minimum distances observed
- Notification procedures
  - Stakeholders (roles and responsibilities regarding fire)
  - Response times and preparations
- Fire fighting procedures
  - Equipment
  - Techniques
  - Training (incl. SOPs, fire drills, etc)

Fire extinguisher trolleys at working face
Fixed extinguisher points on vehicles, at buildings and at stockpiles

Waste Facility Fire Fighting Training

TRAINING	YES	NO
There is a specific training program for fire prevention & extinguishment		
New employees are given basic fire training		
Job-specific fire training held for employees on a regular basis		
Personnel familiar with applicable Material Fire Data Sheets		
All personnel familiar with emergency evacuation plan		
Training documentation current and accessible		
The guests of the landfill are informed that have to follow the staff's instructions		

Source: ISWA Landfill Operational Guidelines (3rd edition)

Landfill Fire Preparedness Checklist

LANDFILL	YES	NO
There is a sufficient stockpile of earth close to the working face		
There is on site available equipment to move earth		
Alternative working face has been planned		
There is adequate supply of water under pressure for fire-fighting purposes		
There is a water storage tank for fire-fighting purposes		
Fire-fighting equipment is readily available		
Record-keeping procedures for all fires		
Electricity generators are available for use		
There is suitable access road for the fire engine to reach the working face and the burning mass		
All the equipment maintenance procedures are followed		
All flammable materials are stored properly		
The most dangerous locations of the landfill for fire, are signed properly		
The emergency telephone numbers (fire department, hospitals, police etc) are displayed in approachable places		
There is an adequate network of lightning conductors for protection from lightning strike		

Source: ISWA Landfill Operational Guidelines (3rd edition)

Planning, Monitoring and Evaluation

Planning Monitoring and Evaluation

Decision Making - Operator

- Contracted activities vs. in-house operations

Planning

- Operations resourcing
  - Equipment (e.g. tools and machinery)
  - Technical (e.g. Environmental Monitoring and testing)
  - Financial / budget planning

Monitoring

- Performance indicators and/or measures
- Environmental compliance monitoring
- Quality control

Problem Solving

- Adjusting plans and procedures to overcome challenges and meet performance goals.

Operations to decision making and planning feedback loops

Environmental Monitoring and Management Plan

A typical Environmental Monitoring and Management Plan includes the following aspects:

- Introduction
- Waste Acceptance Criteria
- Compaction
- Cover
- Vegetation
- Dust Control
- Mud Control
- Pest Control
- Litter Control
- Fire Control
- Noise Control
- Visual Control
- Odour Control
- Complaints Register
- Landfill Gas Control
- Stormwater Management
- Leachate Control
- Post Closure Management Plan
- Environmental Monitoring and Management

Environmental compliance monitoring

Contents

Factors that affect water samples

- Temperature
- Exposure to light
- Oxidation
- Interaction with suspended solids
- Precipitation
- Carbon dioxide affecting the pH and alkalinity
- Inaction with bottle surface
- Microbial content
- pH of the samples
- Relevance of the above to parameter of interest

Sampling for metals

Sampling Requirements

Typical containers used

Groundwater techniques

Typical approaches

3 Well Volumes – removing a fixed volume of water

Low Flow – flow rate (0.1-0.5 L/min) - avoiding significant drawdown

Passive sampling – taking a discrete sample directly from the well screen

Units of Measurement

Parts per million, billion and trillion

	ppm	ppb	ppt
%	mg/kg	ug/kg	ng/kg
%	mg/l	ug/l	ng/l
100	1,000,000		
10	100,000		
1	10,000		
0.1	1,000	1,000,000	
0.01	100	100,000	
0.001	10	10,000	
0.0001	1	1,000	1,000,000
0.00001	0.1	100	100,000
0.000001	0.01	10	10,000
0.0000001	0.001	1	1,000
	0.0001	0.1	100
	0.00001	0.01	10
	0.000001	0.001	1

Equivalent to…

Comparison

Units of Measurement

Milli to Femtograms

Prefix	Symbol	Multiplication Factor	Example
milli	m	10^{-3}	millilitre (ml)
micro	µ	10^{-6}	microgram (µg)
nano	n	10^{-9}	nanogram (ng)
pico	p	10^{-12}	picogram (pg)
fempto	F	10^{-15}	femptogram (fg)

PCDD/Fs & PCBs

Dioxins, Furans and Polychlorinated Biphenyls

POP	Acronym	Parent compound
Polychlorinated biphenyls	PCB	209 congeners
Polychlorinated dibenzo-p-dioxins	PCDD	75 congeners
Polychlorinated dibenzofurans	PCDF	135 congeners

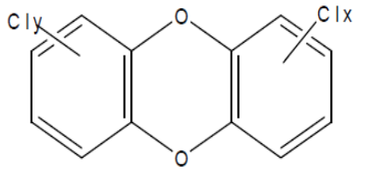
POP	Air	Soil	Water
PCBs	PCB with TEFs (12 congeners) 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169 and 189	PCB with TEFs (12 congeners) 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169 and 189	PCB with TEFs (12 congeners) 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169 and 189
PCDD/PCDFs	2,3,7,8-substituted PCDD/PCDFs (17 congeners)	2,3,7,8-substituted PCDD/PCDFs (17 congeners)	2,3,7,8-substituted PCDD/PCDFs (17 congeners)

Polychlorinated dibenzo-*p*-dioxins (PCDDs)
Polychlorinated dibenzofurans (PCDFs)
Polychlorinated biphenyls (PCBs)

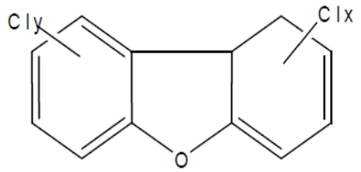
PCDD/Fs & PCBs

Dioxins, Furans and Polychlorinated Biphenyls

Generalised structure of dioxins (PCDDs) and furans (PCDFs).



PCDDs



PCDFs

Homologue	Abbreviation
Dioxins (PCDDs)	
Tetrachlorodibenzo-p-dioxin	TCDD
Pentachlorodibenzo-p-dioxin	PeCDD
Hexachlorodibenzo-p-dioxin	HxCDD
Heptachlorodibenzo-p-dioxin	HpCDD
Octachlorodibenzo-p-dioxin	OCDD
Furans (PCDFs)	
Tetrachlorodibenzofuran	TCDF
Pentachlorodibenzofuran	PeCDF
Hexachlorodibenzofuran	HxCDF
Heptachlorodibenzofuran	HpCDF
Octachlorodibenzofuran	OCDF
Polychlorinated biphenyls (PCBs)	
Tetrachlorobiphenyl	TCB
Pentachlorobiphenyl	PeCB
Hexachlorobiphenyl	HxCB
Heptachlorobiphenyl	HpCB

PCDD/Fs in Landfill Leachate

Diox

Persistent Organic Pollutant (POP)	Specific Form / Isomer	Data Source Reference	Number of Landfills Assessed	Landfill Location	Landfill Type / Composition	Landfill Age when Sampled	Sampling Method / Containers	Sample / Extract Preparation	Analytical Method Employed	Method Detection / Quantification Limit (ng/L)	Maximum POP Concentration in Landfill Leachate (ng/L)
Unintentionally Produced POPs											
Polychlorinated dibenzo furans (PCDF)	Sum 10 PCDFs	Ham et al 2008	12	Korea	MSW with incinerator residues (IR) and Industrial Waste (IW)	3-15 years	8L	GF/B (1.0 um, glass wool filter), LLE (DCM) KOH/H2SO4/water, copper column, multi-silica gel column and alumina column and active carbon column cleanup	HRGC / HRMS	-	0.114
	Sum 7 PCDFs	Choi and Lee et al, 2005	5	Korea	MSW, IR	10-13 years	-	GF/B, 1.0 um, LLE (DCM) KOH/H2SO4/water, copper column, multi-silica gel column, and alumina column cleanup	HRGC / HRMS	-	0.675
	Sum 10 PCDFs (mean concs)	Dudzinska et al , 2011	6	Poland	MSW, domestic ash	4-30 years	From leachate drainage system. Pre-washed amber glass bottles.	50um glass filters, glass SPE, PTFE filtration, SEC filtration or silica gel clean up	GC-MS/MS	-	311.9
	Sum 10 PCDFs	Casanovas et al. 1994	8	Spain	-	-	-	filtration, LLE (DCM), silica, florisil, alumina, carbon column clean up	HRGC / HRMS	10	6.5
	Sum PCDF	Behnisch et al, 2001	1	Japan	-	-	Brown amber glass	1l Extracted with ENV+ polystyrene copolymer resin	GC / MS	-	0.009
	Sum 10 PCDFs	Lavin et al, 2018	1	Spain	HCH Wastes (some MSW)	29 - 33 years	1L glass bottles. Cooled. Sampled from fractured bedrock landfill.	LLE (DCM). Concentrated to hexane/sulphuric acid. Dried with sodium sulphate. Clean up with silica, basic alumina and activated carbon.	HRGC / HRMS	-	0.410
Polychlorinated dibenzo dioxins (PCDD)	Sum 7 PCDDs	Ham et al 2008	12	Korea	MSW with incinerator residues (IR) and Industrial Waste (IW)	3-15 years	8L	GF/B (1.0 um, glass wool filter), LLE (DCM) KOH/H2SO4/water, copper column, multi-silica gel column and alumina column and active carbon column cleanup	HRGC / HRMS	-	0.933
	Sum 7 PCDDs	Choi and Lee et al, 2005	5	Korea	MSW, IR	10-13 years	-	GF/B, 1.0 um, LLE (DCM) KOH/H2SO4/water, copper column, multi-silica gel column, and alumina column cleanup	HRGC / HRMS	-	0.486
	Sum 7 PCDDs (mean concs)	Dudzinska et al , 2011	6	Poland	MSW, domestic ash	4-30 years	From leachate drainage system. Pre-washed amber glass bottles.	50um glass filters, glass SPE, PTFE filtration, SEC filtration or silica gel clean up	GC-MS/MS	-	59.5
	Sum 10 PCDDs	Casanovas et al. 1994	8	Spain	-	-	-	filtration, LLE (DCM), silica, florisil, alumina, carbon column clean up	HRGC / HRMS	10	6.2
	Sum PCDD	Behnisch et al, 2001	1	Japan	-	-	Brown amber glass	1l Extracted with ENV+ polystyrene copolymer resin	GC / MS	-	0.021
	Sum 7 PCDDs	Lavin et al, 2018	1	Spain	HCH Wastes (some MSW)	29 - 33 years	1L glass bottles. Cooled. Sampled from fractured bedrock landfill.	LLE (DCM). Concentrated to hexane/sulphuric acid. Dried with sodium sulphate. Clean up with silica, basic alumina and activated carbon.	HRGC / HRMS	-	0.011

Table 7 Summary of literature review undertaken regarding Unintentionally Produced POPs in Landfill Leachate

MSW = Municipal Solid Waste, C&D = Construction & Demolition, C&I = Construction & Industrial MSOR = Mechanically Separated Organic Residue, MBP = Mechanical and Biological Pre-treatment, SPME - Solid Phase Microextraction, LLE = Liquid Liquid Extraction, SPE = Solid Phase Extraction, DCM = dichloromethane

Discharge Consents

Table of Ranges or Maximum Concentrations

PARAMETER	ALLOWABLE RANGE OR MAXIMUM VALUE
Temperature (on site)	45°C
PH	6.0 – 9.0
Electrical Conductivity	Establish current level and limit to (current level + 500μs/cm)
DO	No limit, used to monitor trends
COD	80 mg/l
BOD_5	20 mg/l
TOC	40 mg/l
Suspended solids	30 mg/l
Volatile Suspended Solids	10 mg/l
Ammonia Nitrogen	Establish current level and limit to ≤ (current level + 5 mg/l)
Nitrate Nitrogen	Establish current level and limit to ≤ (current level + 20 mg/l)
Total Nitrogen	80 mg/l
Sulphate	1000 mg/l
Chloride	600 mg/l
Zinc	10 mg/l
Copper	1.0 mg/l
Lead	5.0 mg/l
Chromium	5.0 mg/l
Nickel	5.0 mg/l
Faecal coliforms	400 per 100 ml
Oils & grease	100 mg/l
Phenolic compounds	0.5 mg/l
Cyanides	0.5 mg/l
Sulphides	1.0 mg/l
Fluorides	20 mg/l
Total toxic metals	30 mg/l
Arsenic	0.1 mg/l
Chromium	5.0 mg/l
Insecticides	‹ 0.005 mg/l

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Further Reading

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