Teagasc:
Heavy Soils Research Programme
Land Drainage

Teagasc Animal and Grassland Research and Innovation

OSMO Soil Health Project-University of Helsinki

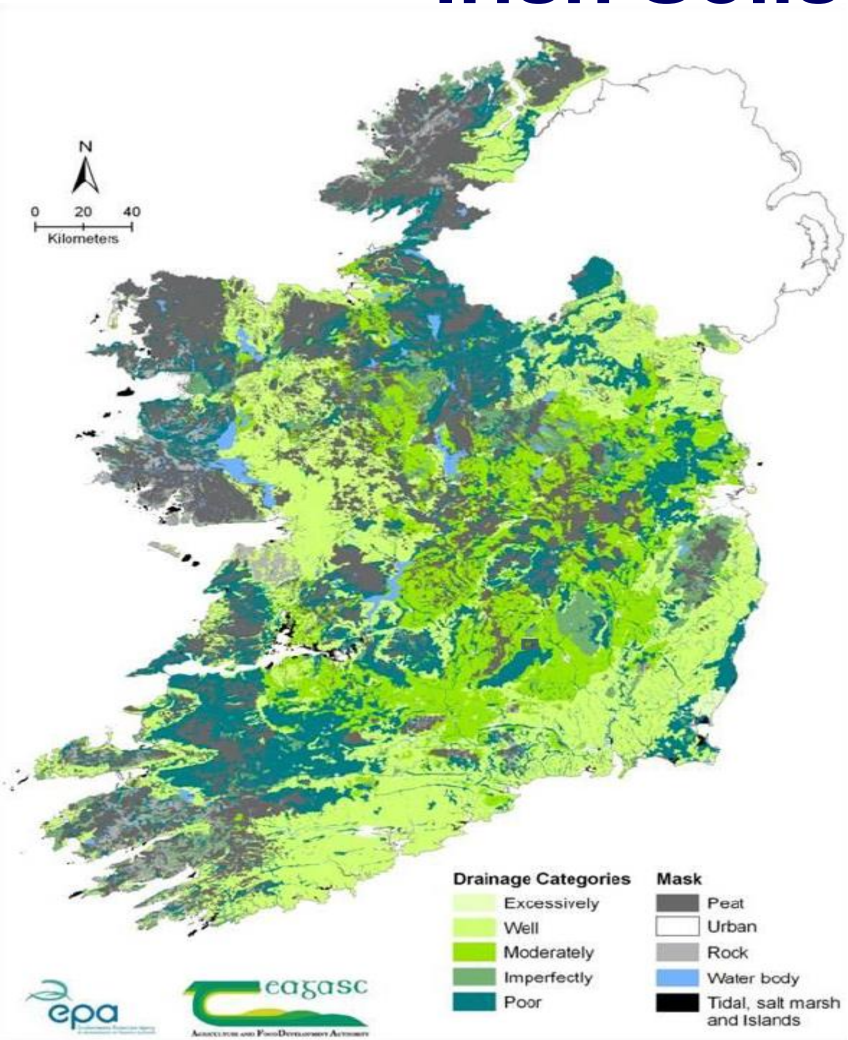
October 3rd/4th 2018

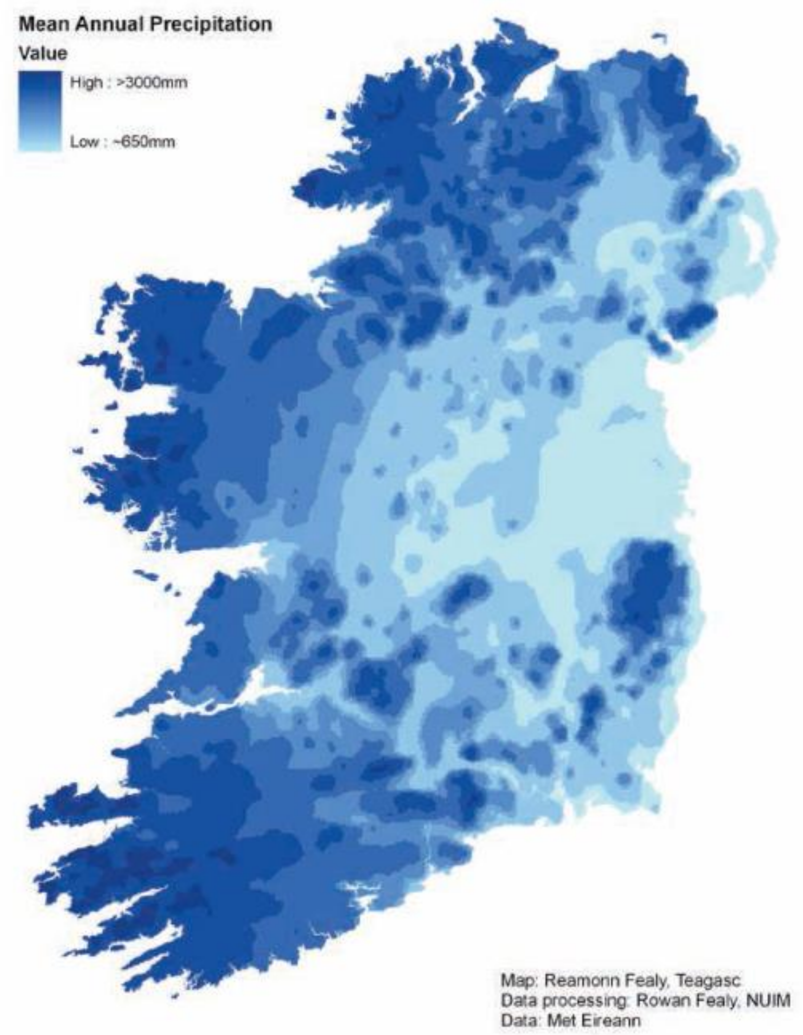
Irish Landscapes






Irish Soils and Rainfall





Irish Agriculture

- 90% of agricultural land area is grassland
- Marginal land occupies just under 50% of Irish land area (Gardiner & Radford,1980)
- Poorly drained and prone to waterlogging
- Land drainage is required to reduce the volatility associated with rainfall



Types of drainage system

- The depth and type of drain to be installed depends entirely on the interpretation of the test pits.

- Two principle types are distinguished:

  - **Groundwater drainage system:** A network of deeply installed piped drains exploiting permeable layers

  - **Shallow Drainage system:** Where soil is heavy and infiltration of water is impeded at all depths and permeability needs to be improved

Groundwater Drainage System

- **A Groundwater drainage system is a network of field drains collecting groundwater which can move through soil layers of high permeability**

- They work by exploiting the natural capacity for movement of water at a certain depth in certain soils

- Often heavy textured soils overlie soils of much higher permeability (**poorer sub-soils closer to the surface and more permeable layers underneath**)

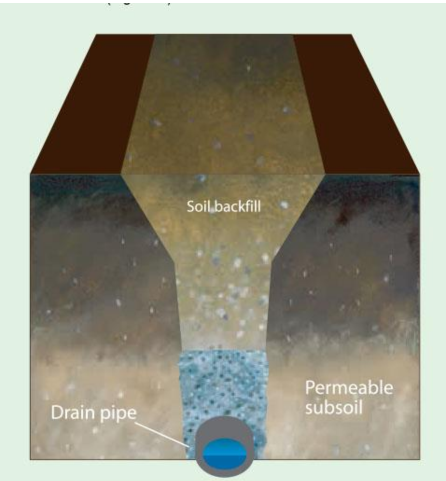
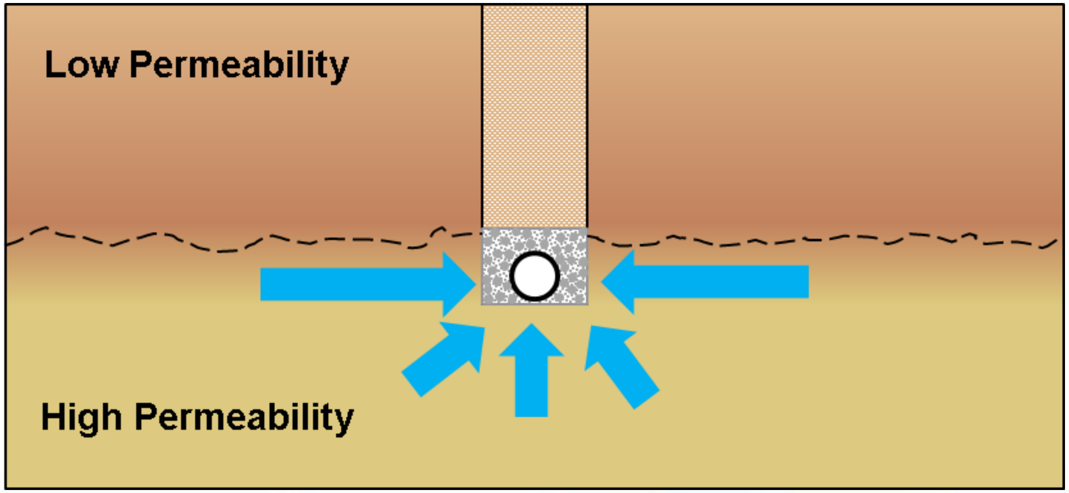


Figure 1. Connection with permeable layer.

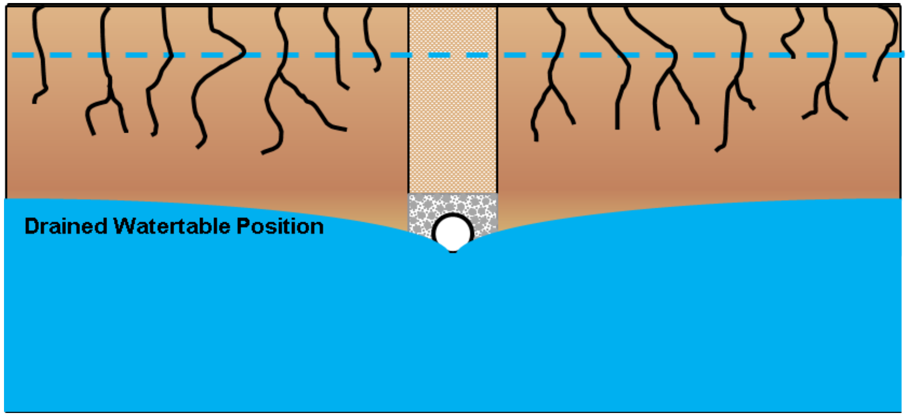


Groundwater Drainage System

- By “tapping” into this natural capacity for water movement the system works by lowering the watertable and reducing the amount of water stored in the soil

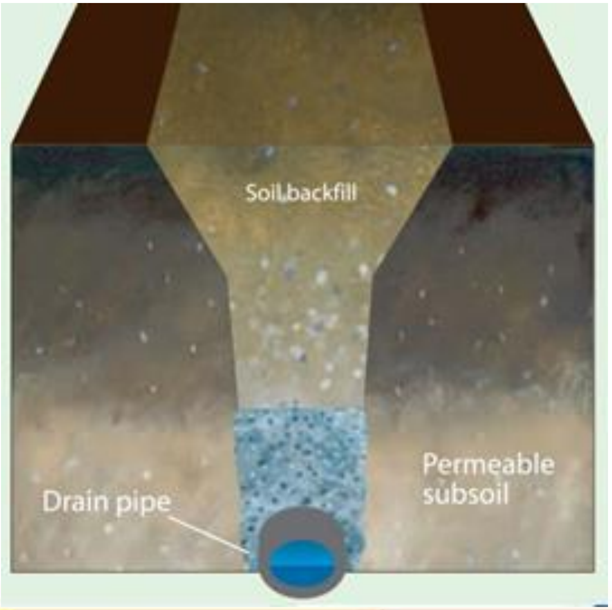
- When it rains water can now infiltrate through the soil. Water storage is reduced so capacity is increased

- By controlling the water table,natural (cracking, root penetration) or artificial (sub-soiling/ripping*)* improvements in permeability in the shallower layers can occur



Backfilling groundwater drains

- Drainage stone should:
  - be filled to a **minimum depth of 30 cm** from the drain bottom
  - provide connectivity with layer of high permeability
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)

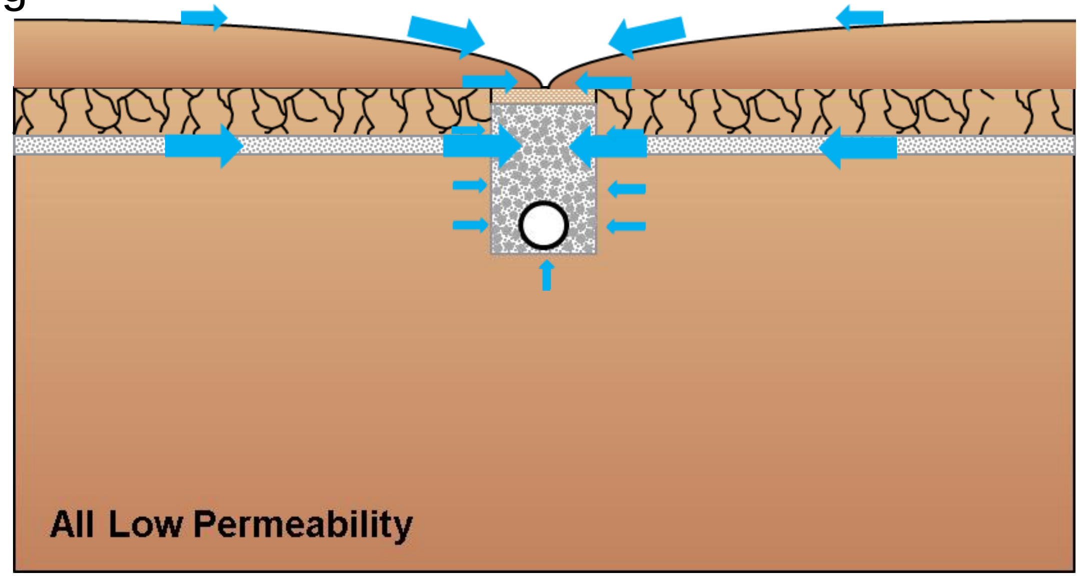


Shallow Drainage System

- **A shallow drainage system is a network of field drains in tandem with surface disruption techniques which promote water infiltration and drainage**

- Used where soil permeability is low at all depths and aims to introduce new pathways for water movement in the soil

- Methods include: Mole drainage, gravel mole drainage, sub-soiling (pan busting) and land forming



Mole Drainage

- Mole drainage comprises closely spaced (1-2 m) shallow **unlined** channels in **cohesive high clay content, stone-free soils**
- They are installed with a tractor mounted mole plough (adjustable depth to 60cm)
- The mole plough creates a channel and new pathways for water movement by fracturing and cracking the soil

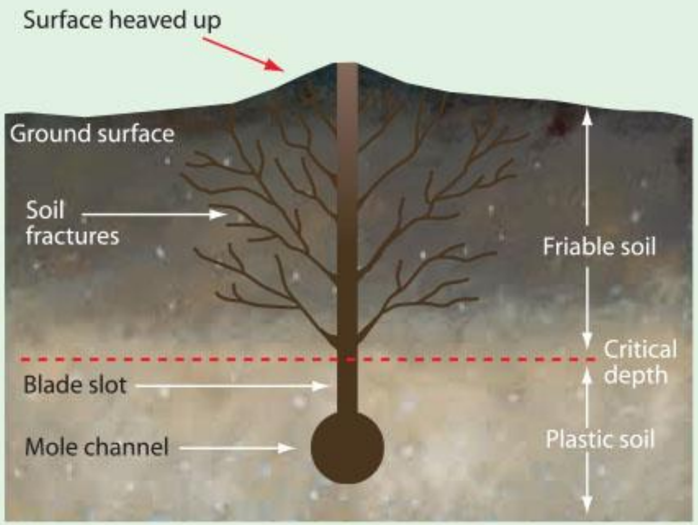


Figure 3. Mole drain showing surface heave.

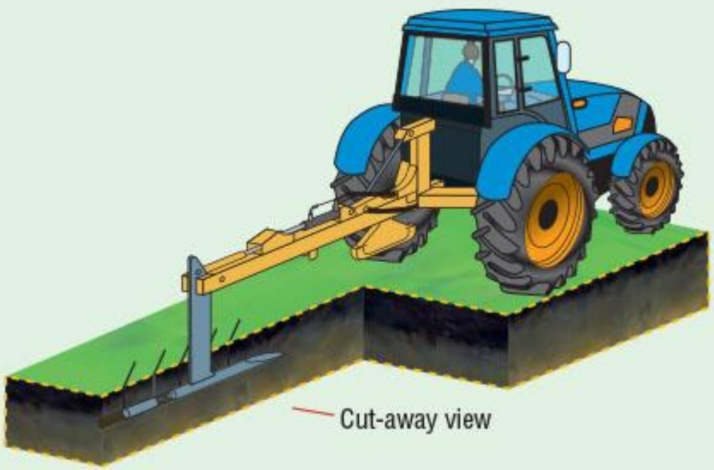
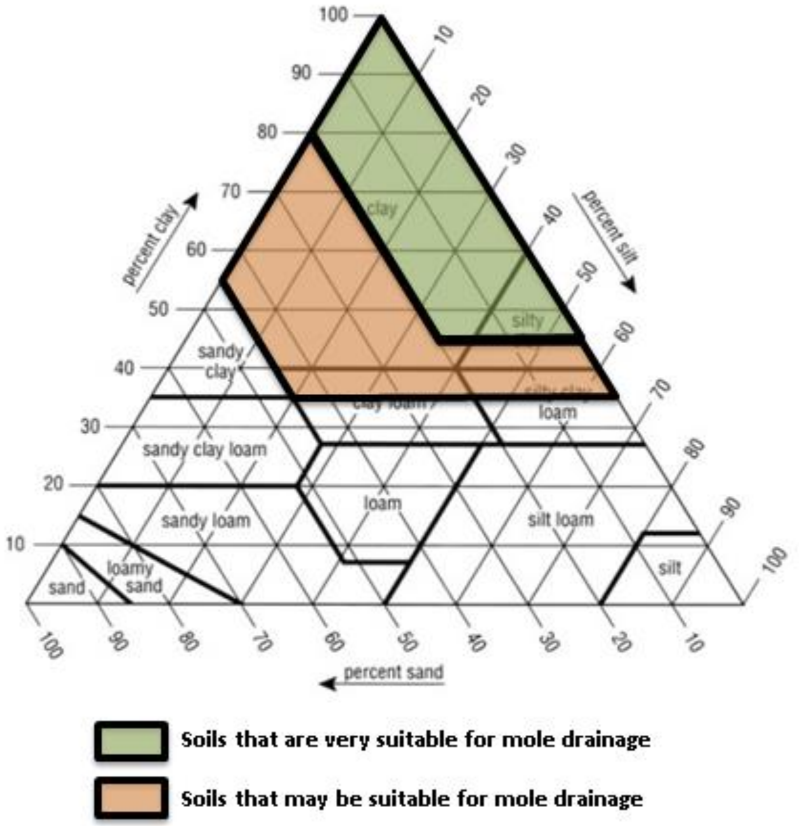


Figure 1. Installation of a mole drain.

Mole Drainage

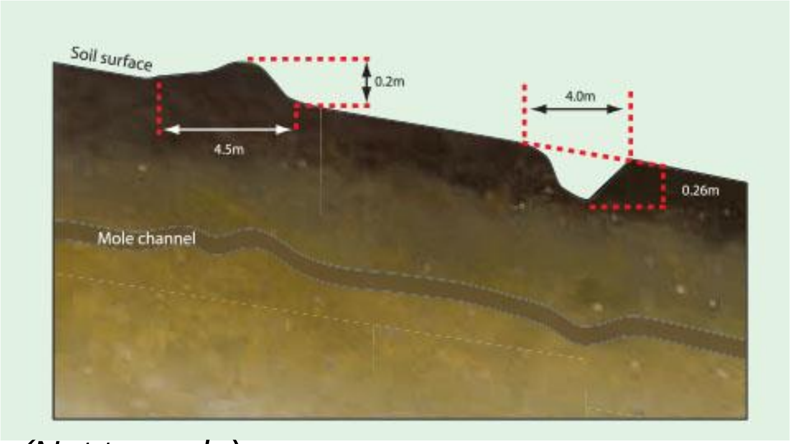
Mole Drainage

- Soil Type suitability(at **Targeted** channel depth):
  - High Clay content (>35%)-"mouldable"
  - **NO** stones/gravels/sand pockets
  - Dry-ready to crack
  - Some questionable scenarios
  - **No definitive test**
  - Lifespan will vary (2-6 years)
  - **Will need to be repeated**



Mole Drainage

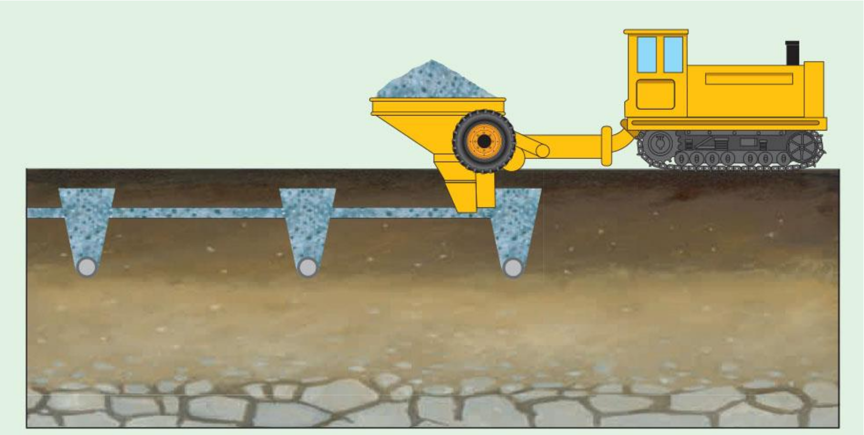
- Spacing 1-2 m apart to maximise cracking/disturbance
- Typically foot is 7-8 cm in diameter, expander is 8-10 cm in diameter
- **Depth targeted**- typically 50-60 cm.
  - Staged approach may be required in very wet soils
- Mole **Up-hill** in direction of maximum fall
- Even gradient (Collector layout must provide outlets from all hollows/depressions)

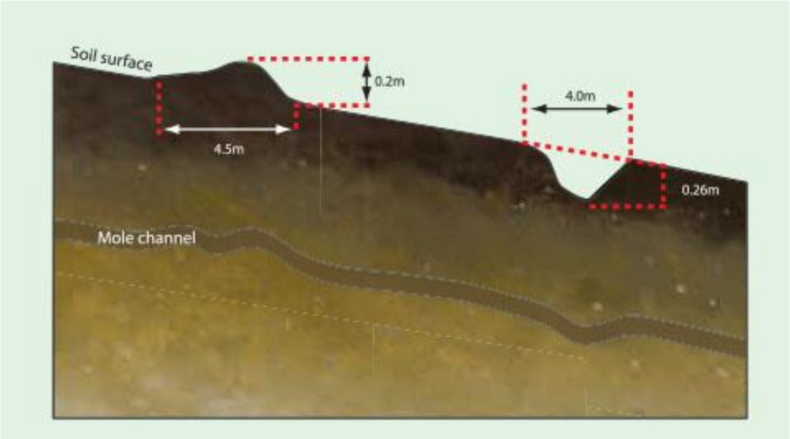


(Not to scale)

Gravel Mole Drainage

- Depth, gravel flow and height of gravel can be adjusted
- Typically gravel mole foot is 8 cm in diameter, chute is 8 cm wide
- Tend to be slighlty wider spaced than mole channels- Approx. 1.5- 2.5 m (Cost!)
- Washed 10-20 mm gravel is used to ensure regular flow from hopper
- **General principles of mole drainage installation apply here also**





Gravel Mole Drainage

- Many soils require closely spaced drainage channels and soil loosening but cannot support unlined channels (texture, stone content etc.)
- Gravel mole drainage offers an alternative where the mole channel and leg slot are **filled with gravel** to provide stability
- They are installed with a tractor mounted gravel mole plough

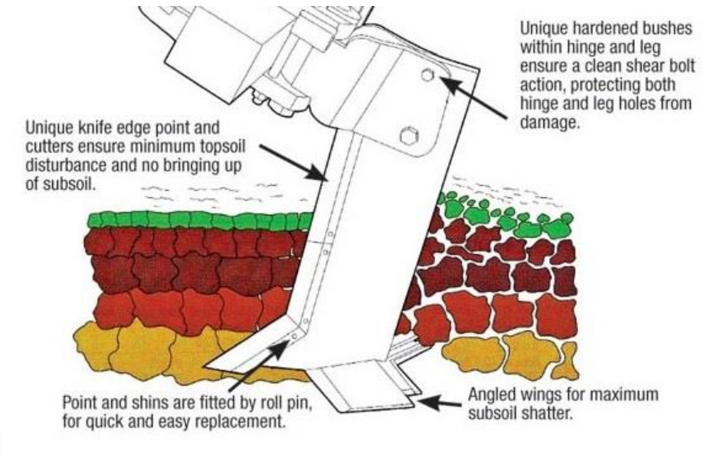
Sub-soiling (Pan-busting)

- Closely related
  - **Sub-soiling:** Refers to general soil loosening
  - **Pan-busting:** Refers to the breaking of a distinct pan or cemented layer

- No attempt to from a stable channel, soil “shattering” is the main aim.

- Generally not effective unless a shallow impermeable layer is broken or used to supplement collector drains

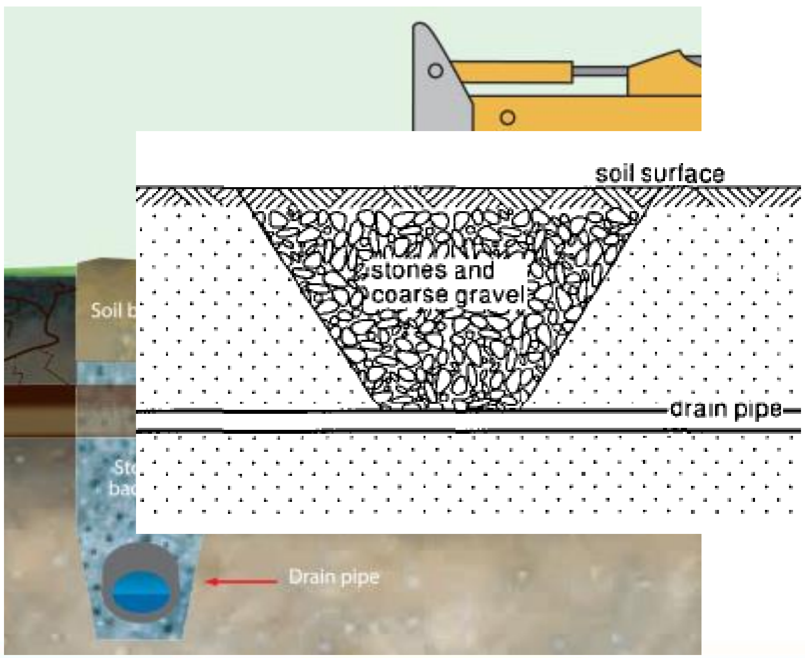
- Limited lifespan

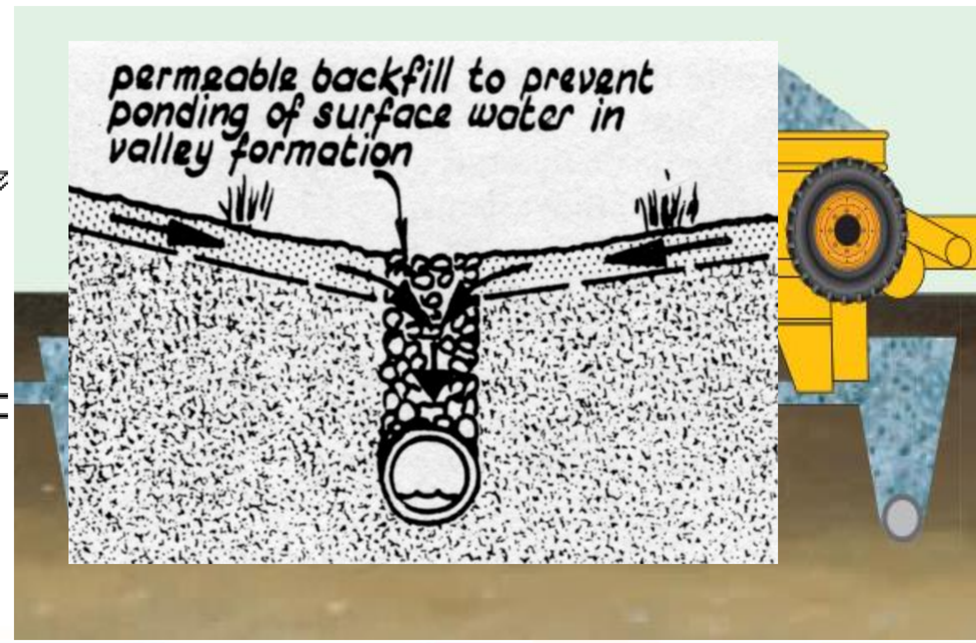


Sub-soiling (Pan-busting)

Backfilling collector drains

- Drainage stone should:
  - fill the trench to within 25 cm of ground surface
  - provide connectivity with mole channels and topsoil
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)





The success of shallow systems!

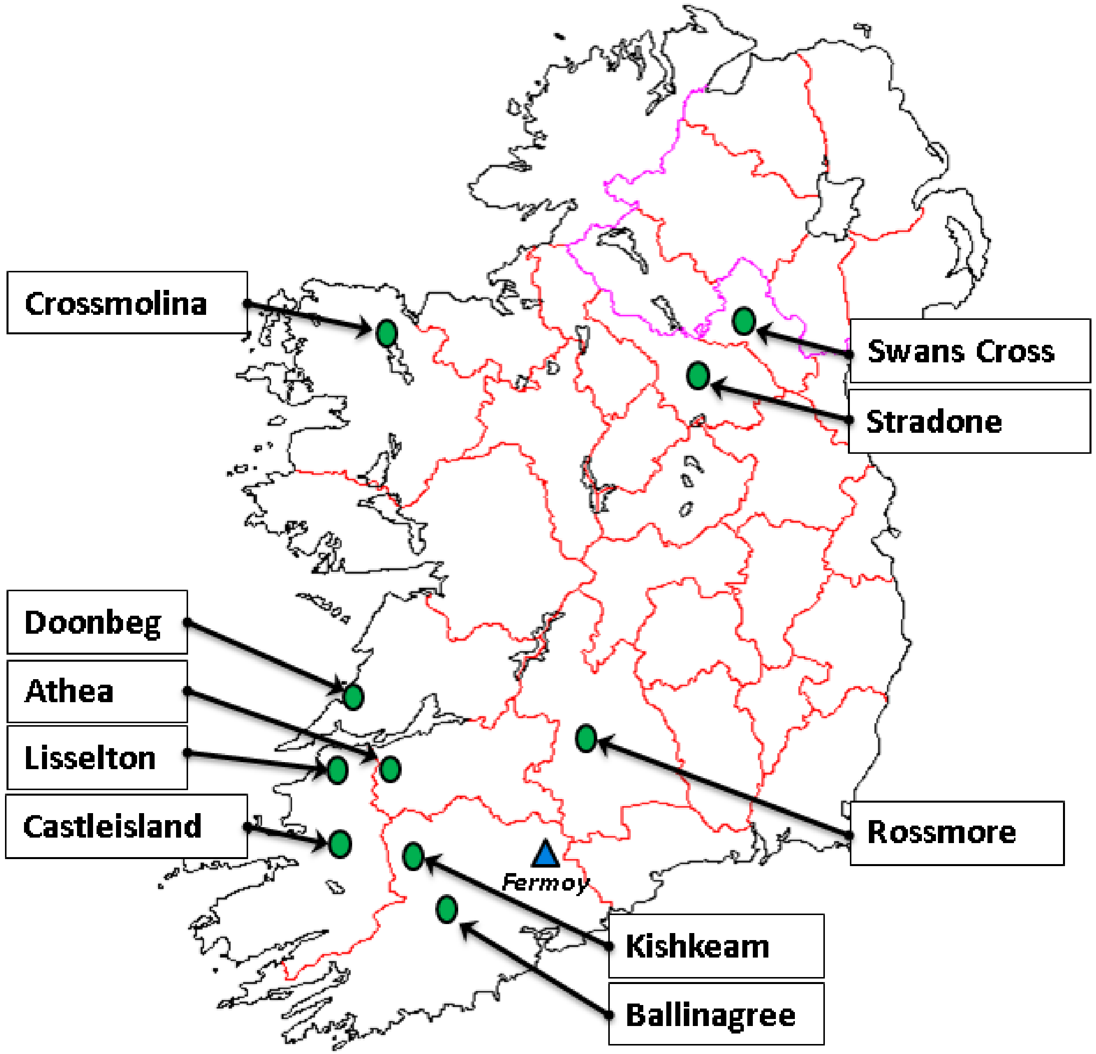
- **Soil Type:** Will mole drains survive? Will sub-soiling have a worthwhile effect? Etc.

- **Timing:** Level of cracking in soils will be dependent on moisture content (weather)
  - Cracking/Shattering and surface traction will be maximised in dry conditions
  - In wet conditions the desired shattering will be replaced my “smearing”
  - Cleaning open drains and installation of collectors can be done in advance and shallow techniques installed when the opportunity arises

- **Equipment:** Implements used must be in good order and fit for purpose
  - Must be able to reach the desired depth
  - And create the desired effect
  - Sufficient power and traction should be available to provide an even pull

- **Capacity:** Dependent on local rainfall
  - Capacity is improved by increasing disturbance (reducing spacing,+ subsoiling)
  - Reducing spacing of collector drains
  - Isolating the site from surrounding areas (open drains)

Heavy Soils Programme Farms

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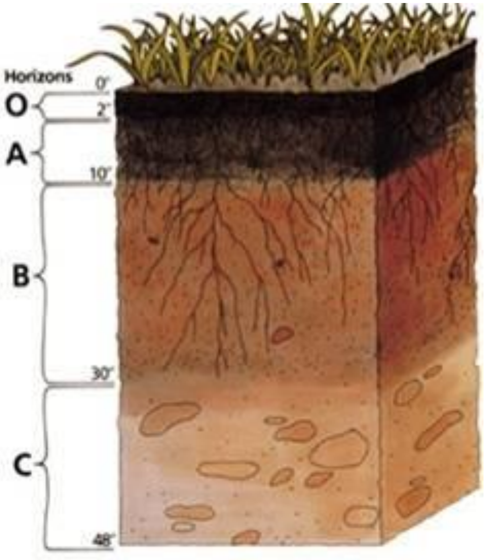
Drainage Investigations

- **When planning a drainage system an investigation into the causes of poor drainage must first be undertaken**
- No “one size fits all” solution
- A number of test pits (at least 2.5m deep) should be dug within the area to be drained
- As the test pits are dug the faces of the pits are observed
- **Are there layers impeding or permitting water movement ?**



Soil test pits- what to note?

- Indicators of permeability
  - Groundwater seepage: if present and approximate rate
    - **Not** the collection of surface water!

Soil test pits- what to note?

- Indicators of permeability
  - Brittleness/Collapse- often hand in hand with water seepage

Soil test pits- what to note?

- Indicators of permeability
  - Pans (Iron, Manganese, Plough) or cemented layers

  - Soil Texture

Soil test pits- what to note?

- Indicators of permeability
  - Soil Porosity
  - Soil Structure

VOIDS (POROSITY): Voids include all space in the soil. Porosity φ is the fraction of the total soil volume that is taken up by the pore space.

Grade of structure: Describes the grade of development of the structure.

Table 35: Classification of the grade of structure

Code	Definition	Description
WE	Weak	Aggregates barely visible in situ and only weak arrangement of natural surfaces that break when gently disturbed.
WM	Weak to moderate	Show weak and moderate properties
MO	Moderate	Aggregates are visible in situ and there is a distinct arrangement of material. When disturbed it breaks into a mixture of entire and broken aggregates.
MS	Moderate to strong	Show moderate and strong properties
ST	Strong	Aggregates are clearly visible in situ and there is prominent arrangement of material. When disturbed it breaks into distinct whole aggregates.

Table 51: Reco

Cod
VF
F
M
C
VC

Good: Soils have many macropores between and within aggregates

Moderate: Macropores are fewer but are present on close examination

tructure: Type of soil st … enic ped formation.
basic natural types of st … d codes are given.

Poor: No visible macropores, massive structureless smooth surfaced, sharp edges

Figure 8: Soil structure types and their formation (FAO, 2006)

Table 52

L	Low	2-5%
M	Medium	5-15%
H	High	15-40%
VH	Very High	> 40%

(Irish Soil Information System: Soil Profile handbook, 2008)

Soil test pits- what to note?

- Indicators of permeability
    - Consistence

Table 40: Classification of soil stickiness

Code	Definition	Description
NST	Non-sticky	No soil material adheres to thumb and finger after release of pressure
SST	Slightly sticky	Soil material adheres to thumb and finger after release of pressure, but it is easily removed.
ST	Sticky	Soil material adheres to thumb and finger after release of pressure, and tends to stretch and pull apart rather than coming away from each digit
VST	Very sticky	Soil material adheres strongly to thumb and finger after release of pressure, and stretches when fingers are separated

Plasticity: Plasticity is the ability of soil material to change shape continuously under the influence of an applied stress and to retain the compressed shape on removal of stress.determined by rolling the soil in the hands until a wire about 3 mm in diameter has been formed (FAO, 2006) (Table 41).

Table 41: Classification of soil plasticity

Code	Definition	Description
NPL	Non-plastic	No wire is formable
SPL	Slightly plastic	Wire formable but breaks immediately if bent into a ring; deformation by slight force
PL	Plastic	Wire formable but breaks if bent into a ring; deformation by slight to moderate force
VPL	Very plastic	Wire formable and can be bent into a ring; deformation by moderately strong to strong force

If moist

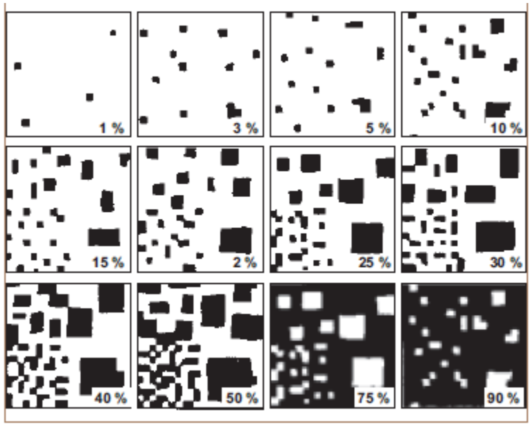
If wet

Plasticity/Stickiness

(Irish Soil Information System: Soil Profile handbook, 2008)

Soil test pits- what to note?

- Indicators of permeability
  - Stone content
  - Orientation

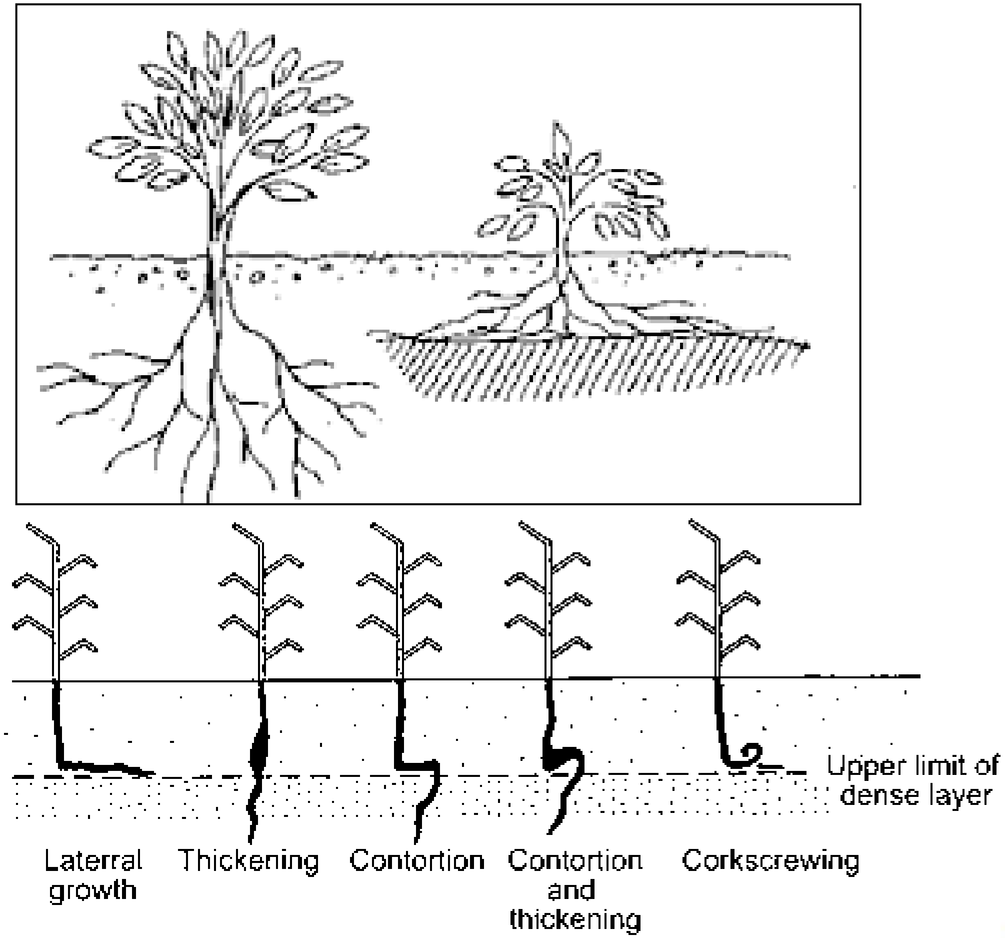


(FAO, 2006)

The Irish Agriculture and Food Development Authority

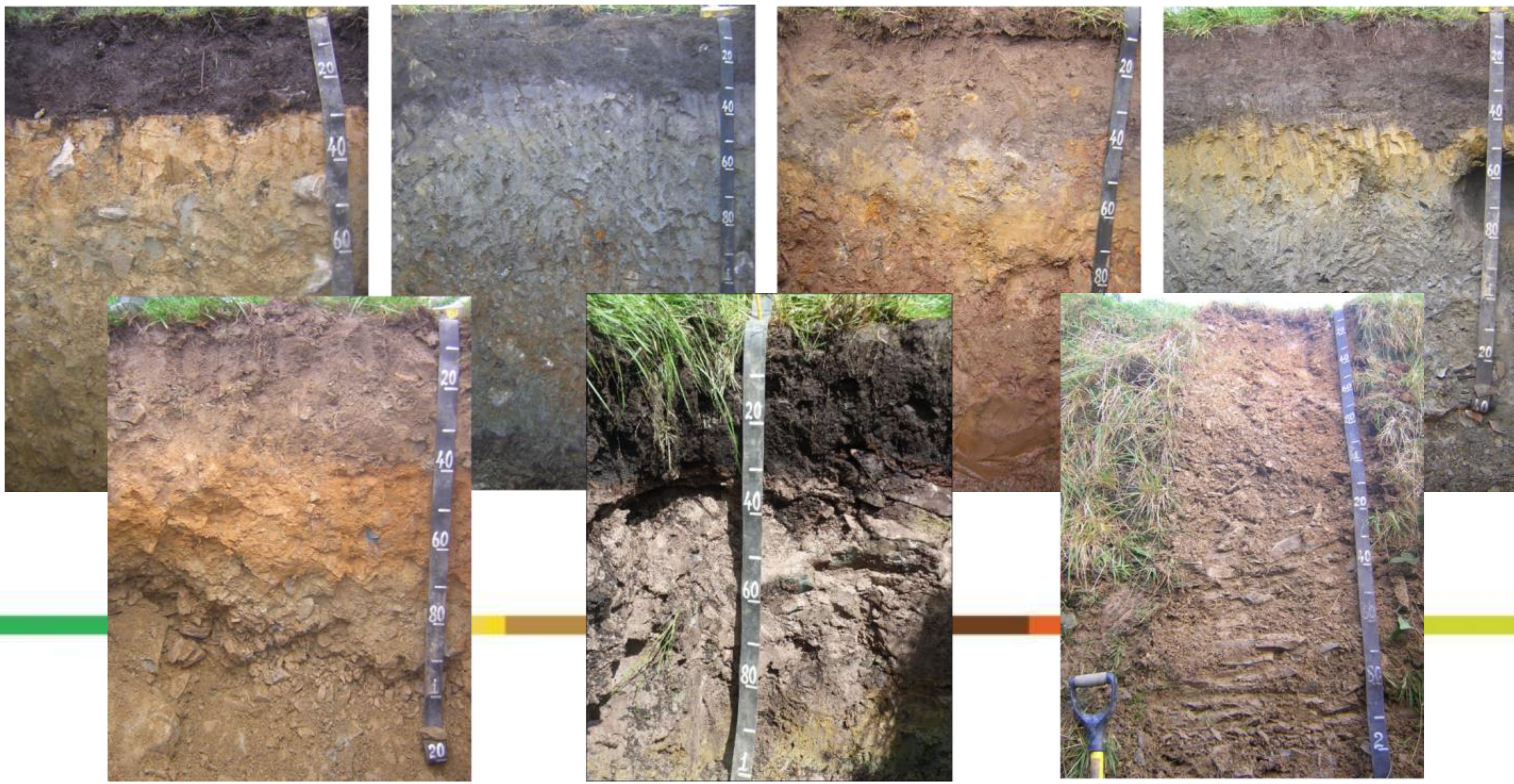
Soil test pits- what to note?

- Indicators of permeability
  - Rooting condition, orientation and depth



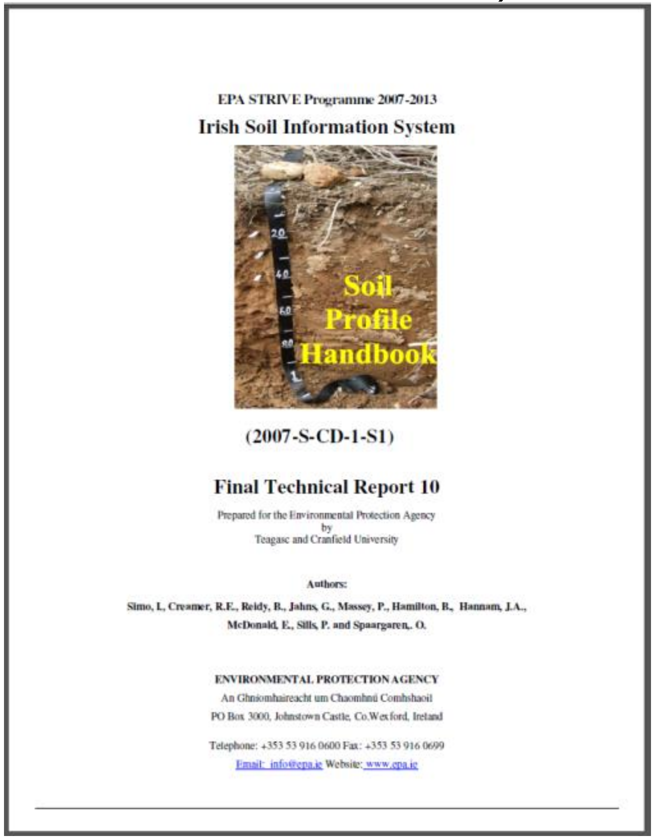
Soil test pits- what to note?

- Indicators of permeability
  - Colour- Main colour
    - Rich browns: good quality, little drainage issues
    - Greys/Blues: gleyed, heavy, water logged
    - Blacks: High organic matter
    - White/light: leached



Describing Soils-Guidelines

(Irish Soil Information System:
Soil Profile handbook, 2008)


EPA STRIVE Programme 2007-2013

Irish Soil Information System

Soil Profile Handbook

(2007-S-CD-1-S1)

Final Technical Report 10

Prepared for the Environmental Protection Agency
by
Teagasc and Cranfield University

Authors:

Simo, I., Creamer, R.E., Reidy, B., Jahns, G., Massey, P., Hamilton, B., Hannam, J.A., McDonald, E., Sills, P. and Spaargaren,. O.

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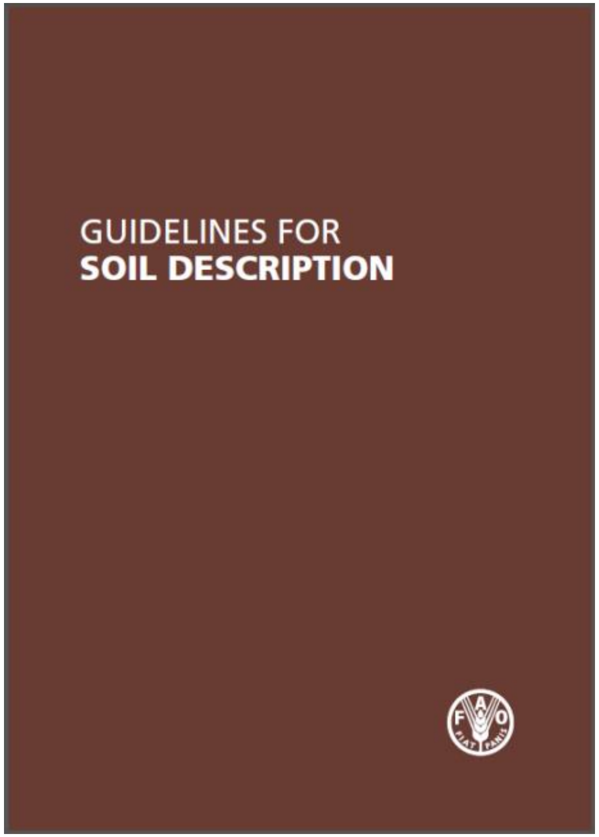
http://gis.teagasc.ie/soils/downloads.php
→Project Technical Reports

(FAO, 2006)

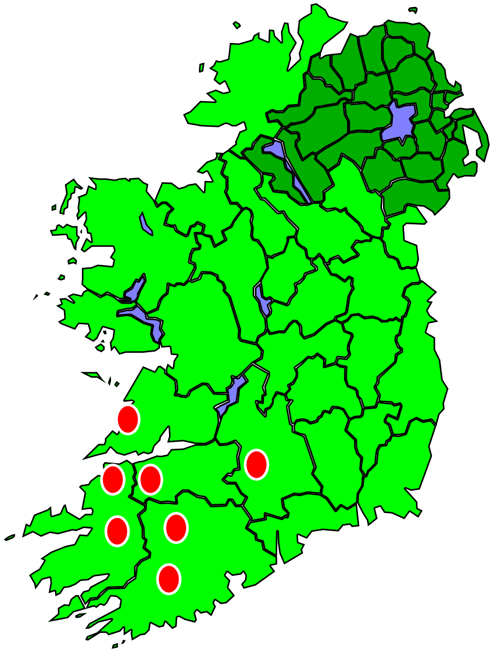


http://www.fao.org/publications/card/en/c/903943c7-f56a-521a-8d32-459e7e0cdae9/

Visual drainage assessment design

- **Selected Indicators**

Water seepage
Texture(sand, silt, clay)
Pan layers
Structure
Porosity
Consistence
Stone content
Colour/Mottling
Root development



Using indicators in each soil profile

- **Soil horizons were defined by distinctions between indicators**
- **Each horizon was classified as highly, moderately or poorly permeable**
- **A site-specific drainage design was prescribed based on these classifications**

Scoring of Visual Indicators

Indicator	Classified by	Classified as	VDA Score	Weighting
Water seepage	Presence	• Water seepage evident	1	A
		• No seepage evident	0	
Pan layers	Presence	• Present	-1	A
		• Not present	0	
Texture	Hand textured (adapted from DEFRA 2005)	• Medium and light textured soils	1	B
		• Heavy textured soils	0	
Porosity	Poor, moderate or good (Shepherd 2009)	• Good	2	C
		• Moderate	1	
		• Poor	0	
Consistence	Stickiness & plasticity (FAO 2006)	• Non-sticky, non-plastic soils	2	C
		• Sticky or plastic soils	1	
		• Sticky and plastic soils	0	
Stone content	Abundance (FAO 2006)	• Stone content > 15%	1	C
		• Stone content < 15%	0	
Root development	Presence	• Present	1	C
		• Not present	0	

Completed by:______________________ Date:_________

Farm:______________________ Field/Paddock:_____ Test Pit No.:___

GROUNDWATER SEEPAGE: Present: YES NO

Depth of groundwater seepage into pit: __________m __________m

TEXTURE GROUP (DEFRA, 2005):

IF PEATY/ORGANIC DESCRIBE AS PEAT

OTHERWISE take MINERAL soil sample, remove any stones, if dry, wet up gradually, kneading between finger and thumb until soil crumbs are broken down. FOLLOW FLOW CHART to get Texture group

Is the moist soil predominantly ROUGH and GRITTY? → YES → Light soils

NO ↓

Does soil mould to form an easily deformed ball and feel SMOOTH and SILKY? → YES → Light soils

NO ↓

Does soil mould to form a strong ball which DOES NOT TAKE A POLISH? → YES → Medium soils

NO ↓

Soil moulds like PLASTICINE, POLISHES and feels VERY STICKY when wet → YES → Heavy soils

Depth range: __________ __________ __________ __________

Texture group:__________ __________ __________ __________

Pan/Cemented LAYERS: Present: YES NO

Depth range(s): ____________m ____________m

ROOTS/ MOTTLES/STONES:

Depth range: ____________ ____________ ____________

Rooting (Y or N): ____________ ____________ ____________

% Stone content:____________ ____________ ____________

Mottles (Y or N): ____________ ____________ ____________

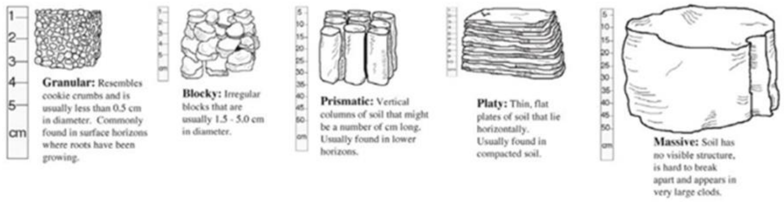
Correspondence: patrick.tuohy@teagasc.ie

STRUCTURE (FAO, 2006) **& POROSITY** (Shepherd, 2009):

GRADE: **Aggregates are "clumps" of soil particles that are bound together**

Weak	Aggregates are barely observable
Moderate	Aggregates are observable
Strong	Aggregates are clearly observable

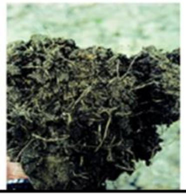
TYPE:



Depth range: __________ __________ __________ __________

Grade: __________ __________ __________ __________

Type: __________ __________ __________ __________



Good: Soils have many macropores between and within aggregates

Moderate: Macropores are fewer but are present on close examination

Poor: No visible macropores, massive structureless smooth surfaced, sharp edges

Porosity: __________ __________ __________ __________

PLASTICITY (FAO, 2006):

Roll the soil in the hands to form a wire about 3 mm in diameter (RED LINE IS 3 mm)

Non-plastic	No wire is formable
Slightly-plastic	Wire formable but breaks immediately if bent
Plastic	Wire formable but breaks if bent into a ring
Very plastic	Wire formable and can be bent into a ring

Plasticity: __________ __________ __________ __________

SOME TYPICAL CHARACTERISTICS

A soil layer may not comply with all of these characteristics the aim is to PICK THE MOST APPROPRIATE CATEGORY for a particular depth range

RED TEXT ITEMS ARE TELLTALE SIGNS IN EITHER CASE, but do not necessarily have to be present for a soil layer to fit that category

Highly permeable (HP)
- Ground water seepage
- Medium/light texture
- Strong granular, blocky or prismatic structure
- Good porosity
- Non-plastic

Poorly permeable (PP)
- Pan layer
- Heavy texture
- Massive or platy structure
- Poor porosity
- Poor root development
- Plastic
- Mottled

Moderately permeable (MP)

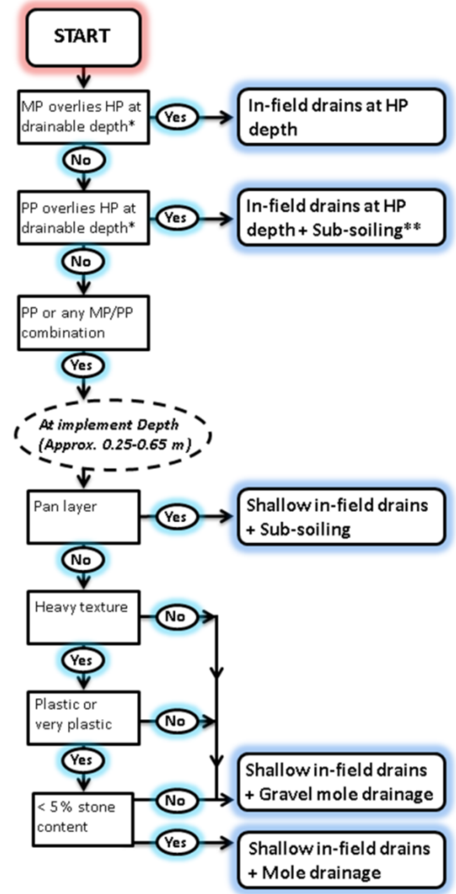
Intermediate between HP and PP
- Medium/light texture
- Moderate grade structure
- Moderate porosity
- Non-plastic
- May be mottled

Permeability Class (TICK to specify)

Depth Range (m)	Poor	Moderate	High

AFTER completing page 1-3 and DEFINING PERMEABILITY CLASS

Drainage SYSTEM TYPE Decision Support



The most appropriate drainage system type for this site is:

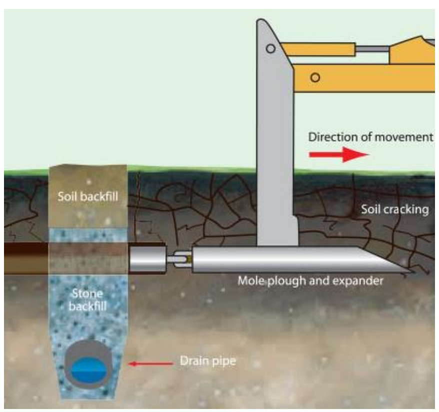
____

____

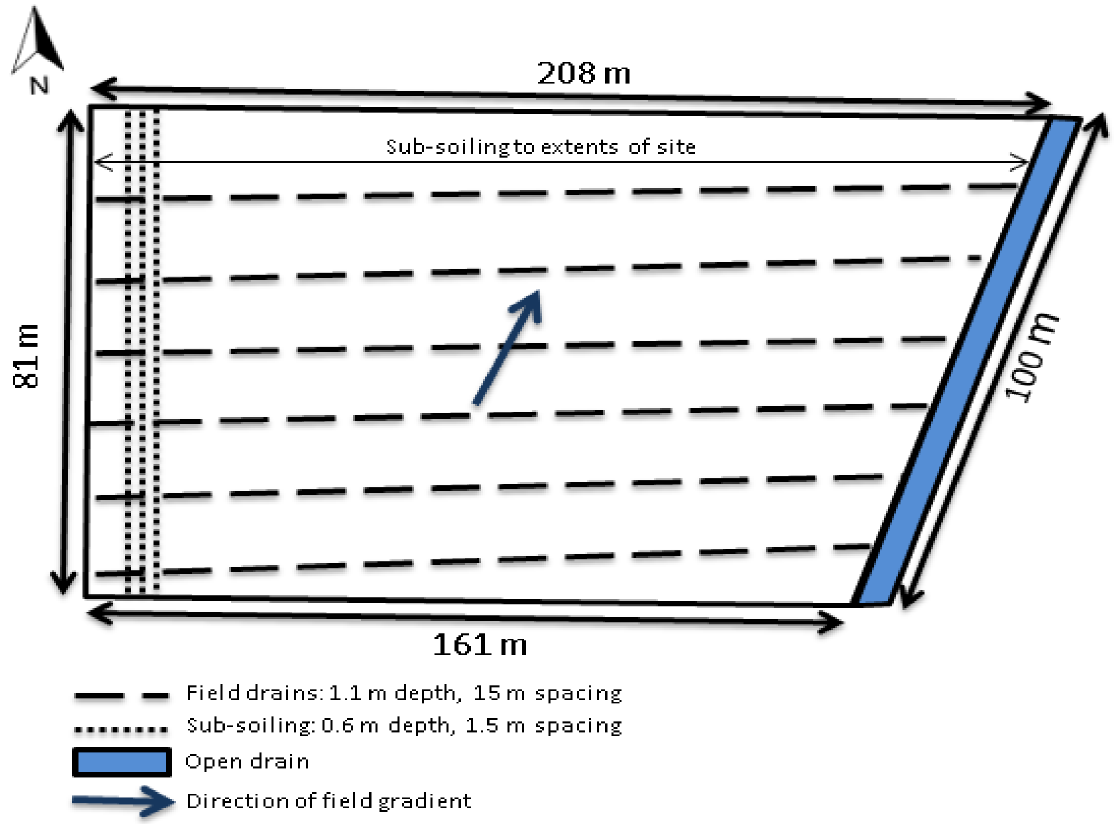
					Mineral Fraction				
Site	Soil type	Horizon	Depth (cm)	OM (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class	Drainage System (Design type: GW or SH)
1	Surface Water Gley	Apg	0-28	5.6	69	16	15	Sandy Loam	1.1: Field drains at 1.6 m depth, 30 m spacing (GW)
		Eg	29-50	0.4	88	8	4	Loamy Sand	
		C	51-90	0.8	59	27	14	Sandy Loam	1.2: Field drains at 1.6 m depth, 15 m spacing (GW)
		Cr	91-140	0.6	69	17	14	Sandy Loam	
2	Ombrotrophic Peat	OA	0-40	68.8	-	-	-	-	2: Field drains at 1.7 m depth, 15 m spacing (GW)
		Of	41-85	89.5	-	-	-	-	
		Om	86-116	3.3	11	61	28	Silty Clay Loam	
		C1	117-141	-	-	-	-	-	
		C2	142-180	-	-	-	-	-	
3	Humic Surface Water Gley	AC	0-30	7.5	51	34	15	Loam	3: Field drains at 1.7 m depth, 20 m spacing (GW)
		BC	31-80	0.7	60	31	9	Sandy Loam	
		Cr	81-116	0.6	48	41	11	Loam	
4	Humic Brown Podzolic	Ap	0-25	11	15	49	36	Silty Clay Loam	4: Field drains at 1.1 m depth, 15 m spacing supplemented by sub-soiling at 0.6 m depth, 1.5 m spacing (GW)
		Bt	26-65	4.4	21	54	25	Silt Loam	
		Cr	66-110	2.3	39	40	21	Loam	
		R	111-220	-	-	-	-	-	
5	Groundwater Gley	Apg	0-26	6.3	21	45	34	Clay Loam	5: Field drains at 0.9 m depth, 15 m spacing supplemented by mole drains at 0.6 m depth, 1.4 m spacing (SH)
		Btg	27-48	2.2	13	49	38	Silty Clay Loam	
		Cg1	49-75	1	12	59	29	Silty Clay Loam	
		Cg2	76-140	0.9	23	50	27	Silt Loam	
6	Humic Surface Water Gley	Ap/O	0-40	59.6	40	26	34	Clay Loam	6: Field drains at 0.9 m depth, 20 m spacing supplemented by gravel mole drains at 0.45 m depth, 1.5 m spacing (SH)
		Btg	41-62	4.5	7	51	42	Silty Clay	
		Cg1	63-140	1.7	13	54	33	Silty Clay Loam	
		Cg2	141-170	0.9	22	55	23	Silt Loam	
7	Stagnic Luvisol	Ap	0-36	8.5	20	45	35	Silty Clay Loam	7.1: Field drains at 0.9 m depth, 20 m spacing supplemented by sub-soiling at 0.5 m depth, 0.6 m spacing (SH)
		BCtg	37-100	1.1	20	50	30	Silty Clay Loam	7.2: Field drains at 0.9 m depth, 20 m spacing supplemented by sub-soiling at 0.5 m depth, 0.6 m spacing and gravel mole drains at 0.45 m depth, 1.5 m spacing (SH)
		Cr	101-190	1.4	34	41	25	Loam	

Land Drainage Design: Kishkeam Farm

Problem Diagnosis



Drainage system design

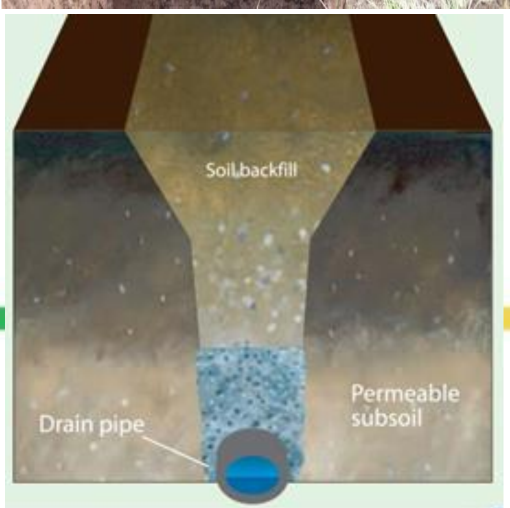


Drainage Costs: Kishkeam Farm

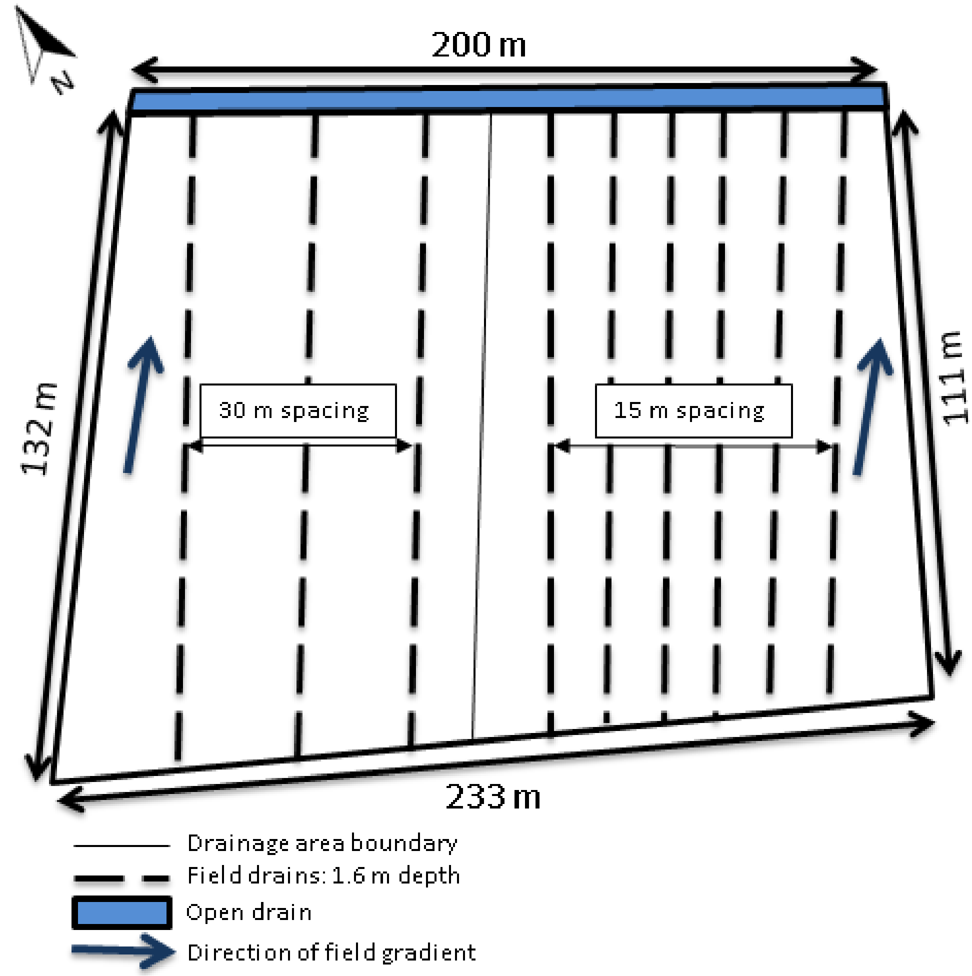
Costs	Total/ha
Drain installation @ €45/hr (36 hrs)	€1,625
Drainage pipe @ €1.03/m (566 m)	€585
Drainage stone @ €10.78/t (101 t)	€1,085
Subsoiling	€125
Drainage cost	€3,420

Land Drainage Design: Rossmore Farm

Problem Diagnosis



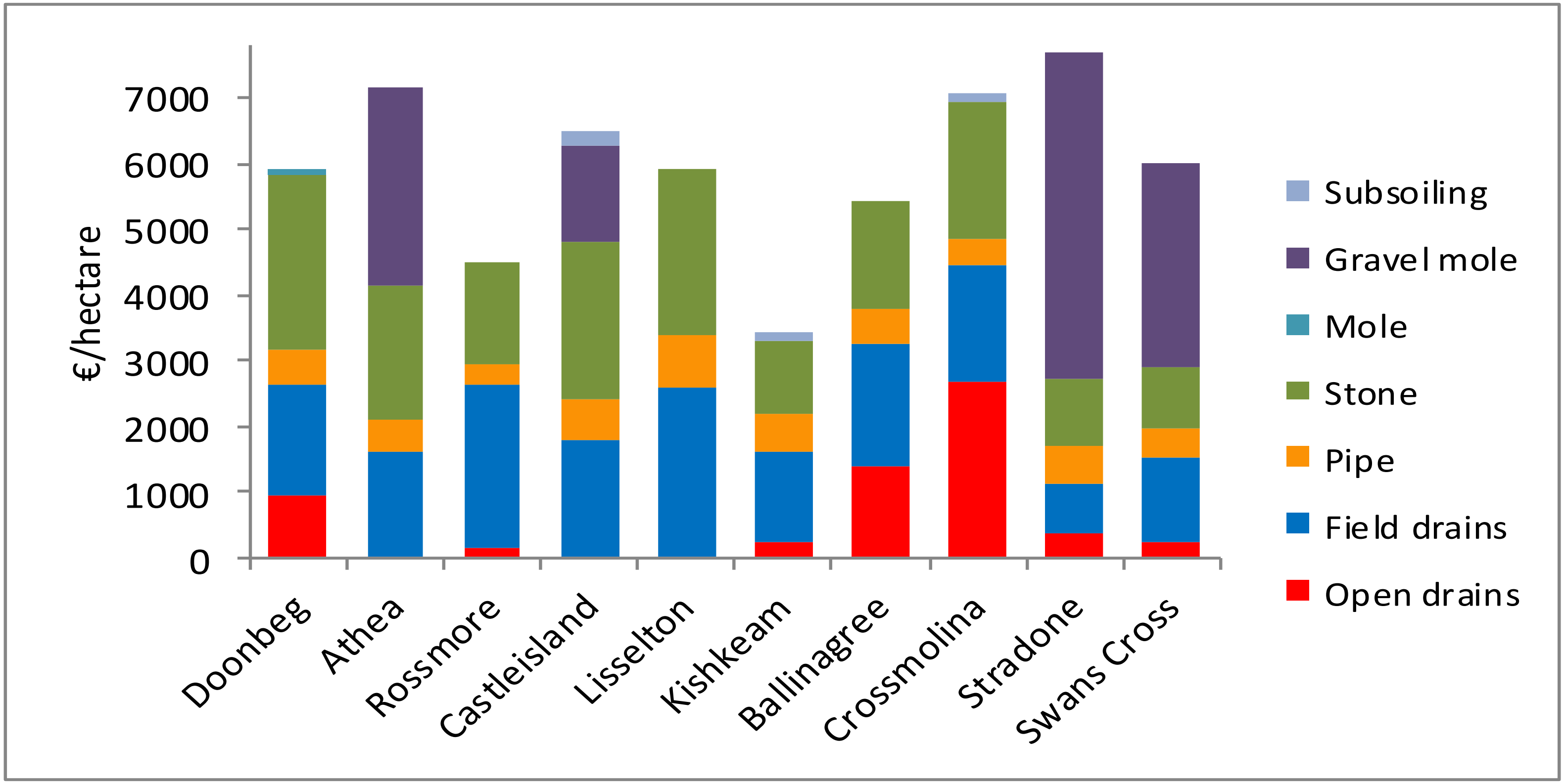
Drainage System Design



Drainage Costs: Rossmore Farm

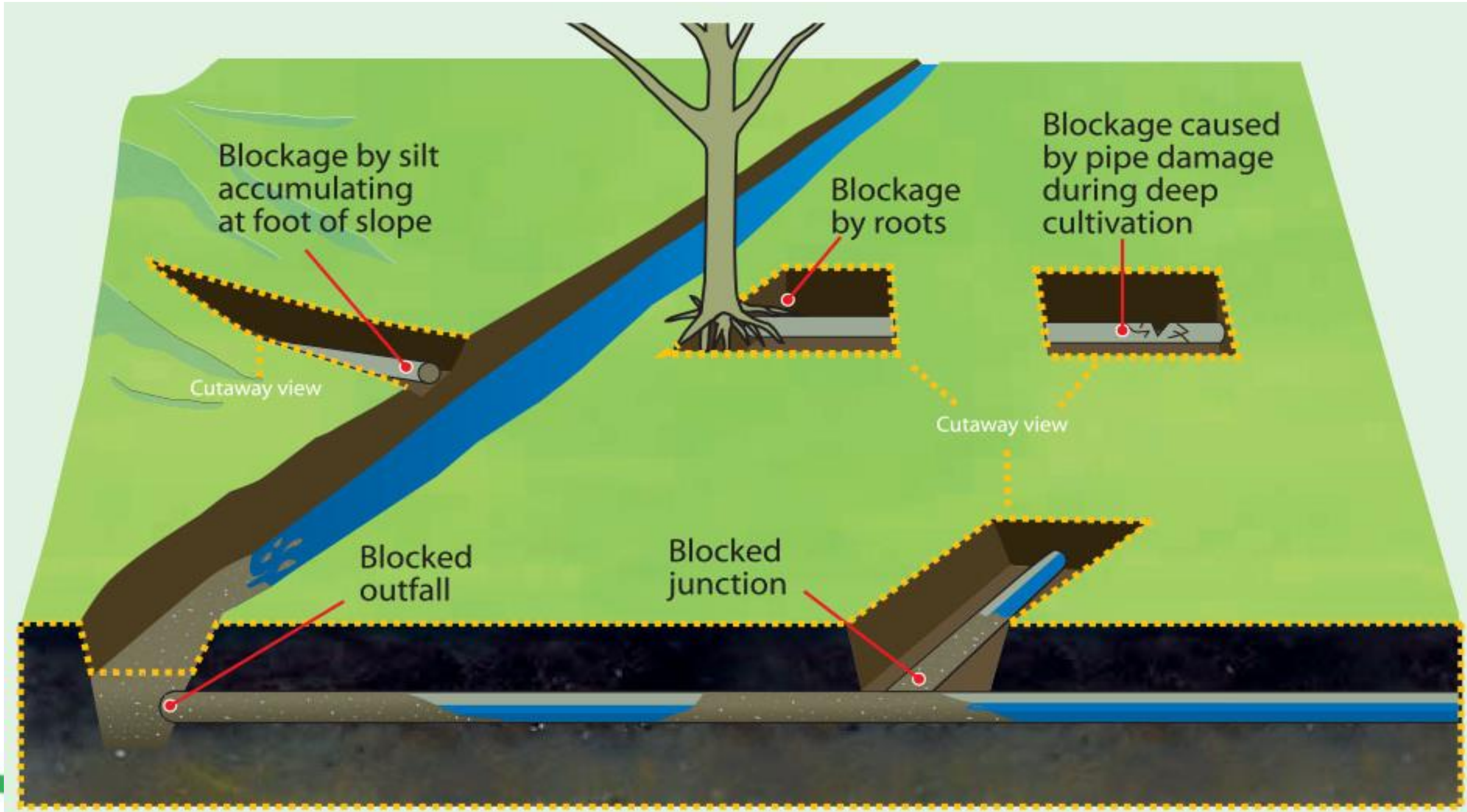
Costs	Total/ha
Drain installation @ €45/hr (55 hrs)	€2,476
Drainage pipe @ €0.70/m (429 m)	€300
Drainage stone @ €11.10/t (141 t)	€1,562
<u>Drainage cost</u>	<u>€4,338</u>

Approximate costs

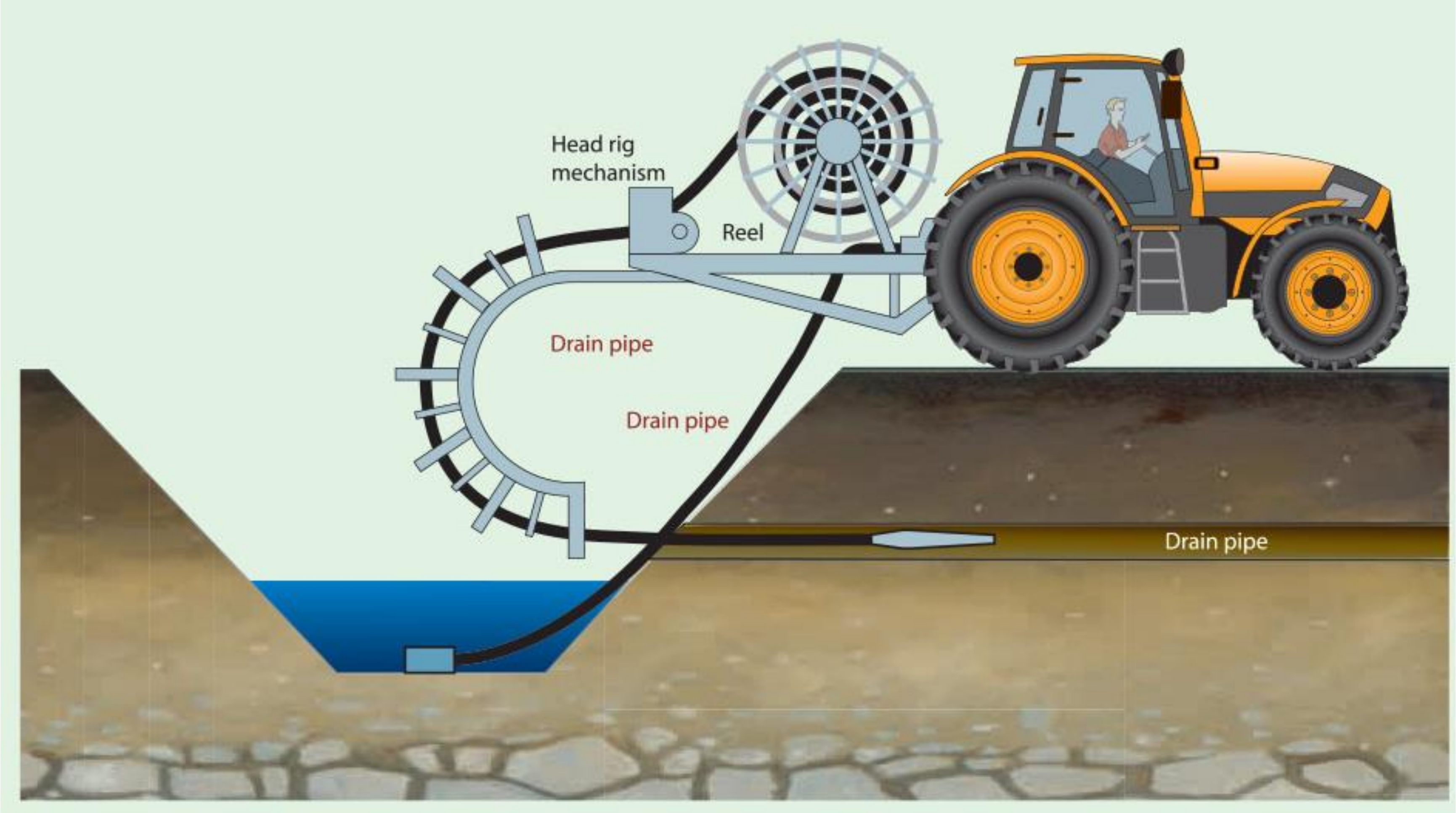


All costs included, high intensity systems. The average cost of drainage systems was €5,960/hectare (€3,420/ha to €7,690/ha)

Maintenance



Maintenance



References

- Teagasc Land Drainage guidebook
- Heavy Soils Open Day booklets
- https://www.teagasc.ie/crops/grassland/heavy-soils/
- Teagasc Manual on Drainage and soil management