Teagasc Heavy Soils Dairy Programme Review

Complied by

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1. Introduction

A large proportion (circa 30%) of milk produced in Ireland originates from farms where the soils that can be classified as heavy. Heavy soils add complexities to the production system that are aggravated by inclement weather conditions. A new research programme has been established focussing on the skills and technologies which will facilitate expansion and maximise profitability on farms with Heavy Soils. This will necessitate the adoption of key technologies including land improvement strategies, quality pasture management, compact calving, increased stocking rates, risk management, genetic improvement, heifer rearing strategies and low cost labour efficient farm infrastructures.

Objectives of Heavy Soils Programme

- The establishment of a research programme to find the most cost effective and efficient means of increasing profitability on heavy soils.
- To test and implement findings from Teagasc, Solohead research on drainage and cow type on programme farms.
- To evaluate commercially focused, expanding family farms demonstrating financially rewarding business growth on heavy soils.
- To hold regular farm focus days to provide timely, accurate and challenging information to help decision making.
- To provide guidance in the design, construction and operation of new low cost grass-based dairy farm infrastructure, incorporating the most efficient and cost effective technologies for land and pasture improvement.
- Inform the dairy industry about activities and innovations coming from the project.

2. Participants

The programme is a collaborative project between Kerry Agribusiness, Dairygold, Tipperary Co-Op and Research and Advisory personnel from Teagasc. To date seven farmers have agreed to participate in the programme. The farms were selected taking cognisance of 1) the requirement for a range of challenging soil types, 2) regional distribution, 3) potential for sustainable profitability and 4) importantly, willingness of the farmer identified to participate fully in the project.

Over the course of the summer of 2012 all farms were visited to establish soil type, grass utilization challenges and possible drainage solutions. This involved having an excavator on site to dig a number of test holes on each farm .The team was headed by retired colleague Tim Gleeson and included Pat Tuohy, David Trant, Pat Dillon, John Maher, Ger Courtney, Pat Buckley, Jim Kiely (retired colleague), Laurence Shalloo, James Humphreys and James O’Loughlin. At each farm the local advisors were present. The farms selected are described below:

2.1 Danny Birmingham, Mountrivers, *Doonbeg*, Co. Clare

Danny inherited the farm from his late father. A lot of land improvement through drainage and re-seeding has been done over the years and a considerable investment made in farm building infrastructure.

The farm has a peat soil, with poor drainage and is in an area of high rainfall. The current farm operation is totally devoted to dairying and has expanded from 20 cows to 70 cows over the past 10 years with a target of milking 100 cows on the existing land base of 47Ha.

The visit to examine drainage issues took place on Wednesday 1St August 2012.

Picture 1: General view of farm

Drainage History

Drains were installed at various times over the years. Danny's father installed drains at a depth of 750mm filled to within 100mm of the surface at 16 metre spacing and were installed with grant assistance. Danny also discovered deeper drains (1100mm) with yellow land drainage piping which when the outlets were cleared began to work away again.

More recently Danny has used the Connacht Agri piping see Picture 2. This cost €4.50/ metre (€3.50 per metre to buy pipes and €1/metre for digger and labour to install). It has worked well in swampy peat as there is no stone used which means that the use and cost of a tractor and stone cart are avoided.

Picture 2: Connacht Agri pipe with filter around it

General Observations

- 1200 mm rainfall, 500 mm evaporation, main problem is excess rainfall
- Cheapest test of the suitability of a soil for mole draining is to install some, soil physics tests are more expensive
- Planning drainage design 10mm/day for pasture, 20mm/day for vegetables and 25 – 40mm for playing field
- Rate of rainfall averages 1mm /hour when raining with a range of .01 to 20 – 30 mm/hour
- Conventional drainage pipes need stone around them for a) To cat as a filter stopping the perforations in the pipe from blocking with fine soil particles , b) Hydraulic improver: increase the effective diameter of the pipe thus reducing radial resistance by providing a zone of high

hydraulic conductivity surrounding the pipe and c) Bedding: Provide support for the pipe and prevent collapse

- What stone suitable for bog? Clean stone essential, small stone around the pipe, larger stones on top. Cementing of limestone tends to be caused by unclean stone (dust in mix) rather than the stone itself.
- With effective drainage there should be no surface water.
- Mole drain costs. Collectors drains at 20 m spacing €3000/ha, gravel moles €1500/ha, naked moles €125/ha.
- A nearby field that flooded regularly was drained by installing shallow drains 500mm in depth and 2.2 metres apart.
- Deep drains where they work have the advantage of a) lowering water table, b) can be designed with a much smaller assumed drainage co-efficient (depth of the drains in the profile provides a buffer against extreme rainfall loading on the drains so weekly rain can be averaged out), c) because of a lower water table deeper rooting occurs. Not suggesting that they are suitable for this farm.
- During a discussion on deep drainage at the first hole, there was a view that cutting the open drains down to the depth of the fissured shale material would bring about drainage of the field. It would indeed be a help but only up to a short distance from the open drain. It must be remembered that drains in a drainage layer such as the fissured shale at 20m spacing's have an influence on just that soil at 10m either side, just because an open drain is excavated to intersect a drainage layer doesn't mean it will have a greater influence than an equivalent deep drain.
- It is thought that the poorly structured glacial till overlying the fractured shale layer is too thick and dense in nature to facilitate the desired cracking needed for a satisfactory deep drainage system, particularly under the rainfall levels particular to the area.
- The alternative and more costly drainage solution is a disruption technique (mole drainage or gravel mole drainage) in tandem with a collector drain network.

Test hole 1 near Cree River

Depth cm	*Description*
0 - 40	Peat
40 - 70	White silty clay with a stone layer, quite bouldery
70 - 125	Less stony, poorly structured, very dense glacial till, upper carboniferous
125 - 240	Slightly looser and better structured sandstone influence, fissured shale, substantial ingress of water

Test Hole 2 near Cree River

Depth cm	Description
0 - 40	Peat
40 - 70	White silty clay
70 - 125	Poorly structured, very dense Glacial till, Upper carboniferous
125 -300	Slightly looser and better structured sandstone influence

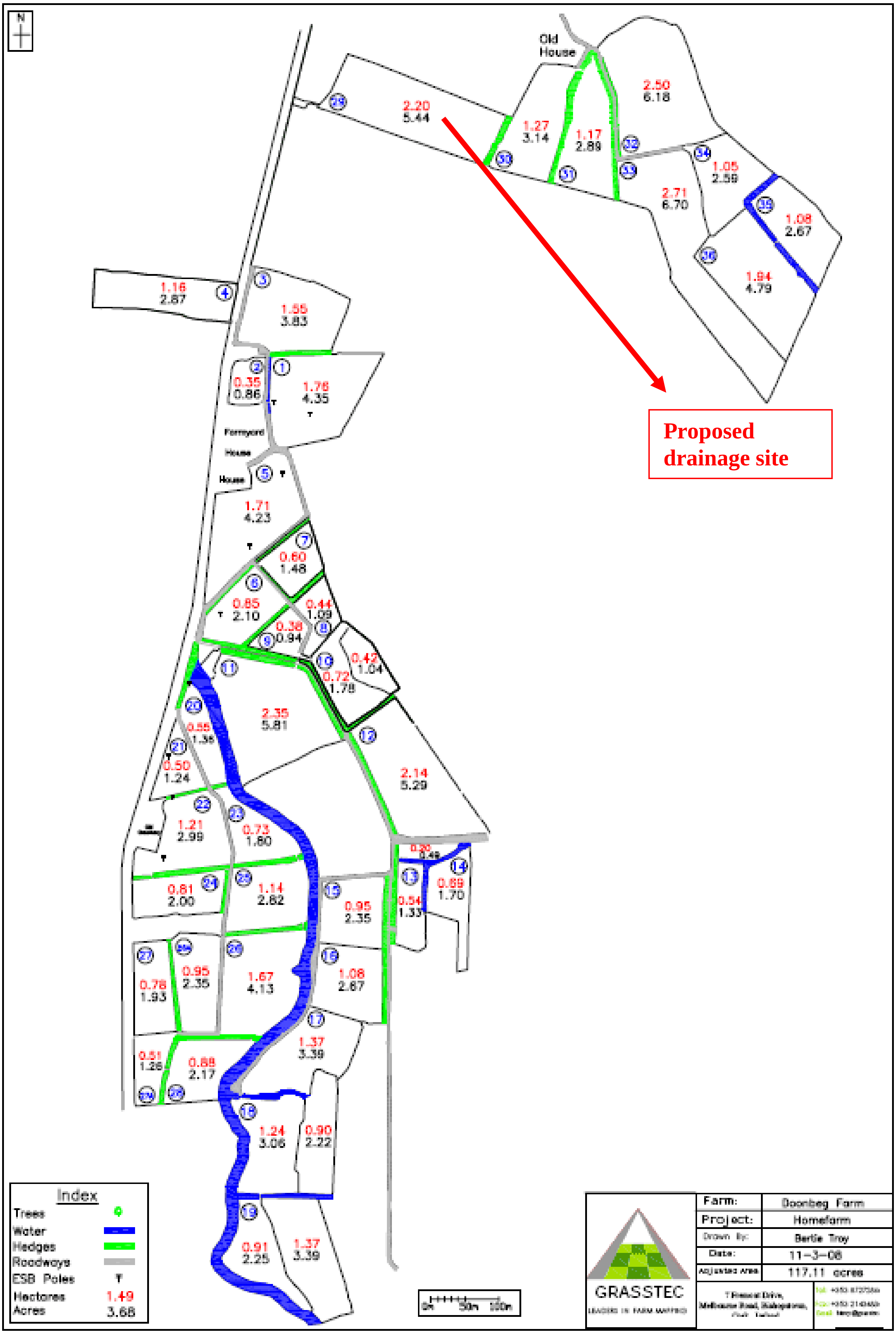
Test hole 3 near Doonbeg River

Depth cm	Description
0 – 30	Cut away peat
30- 70	White silty clay
80-240	Poorly structured, very dense Glacial till, Upper carboniferous

Test hole 4 near Doonbeg River

Test hole 4 near Doonbeg River - dry piece of ground with wet areas all around

Depth cm	**Description**
0 – 40	Moderate organic top soil, silty loam
40- 70 (varying 0 -30)	Manganese concretions resulting from varying water table
70 - 90	White silty clay
80 – 210	Poorly structured very dense Glacial till Upper carboniferous



N
Old House
Proposed drainage site
Index
Trees
Water
Hedges
Roadways
ESB Poles
Hectares 1.49
Acres 3.68
Farm: Doonbeg Farm
Project: Homefarm
Drawn By: Bertie Troy
Date: 11-3-08
Adjusted Area 117.11 acres
GRASSTEC
LEADERS IN FARM MAPPING

2.2 John Leahy, Woodview, *Athea*, Limerick

John has recently taken over running the farm from his father Jim. The 52 Ha farm near Athea village has a mixture of heavy mineral soil and some peat. Currently 80 cows milking with plans to expand to 90. The drainage farm visit took place on Friday 4th May 2012.

Picture 1

Notes on picture 1.
All on carboniferous shale.
Blanket peat on top of hill.
Side of hill (green grass) soil surface is shallower, rock underneath more fissured shale on top giving good drainage as water is moving down, spring rising in field confirming assumptions.
Base of hill area that was turned last year.

At bottom of the field soil depth begins to increase and get wetter. Rock may have been protected during ice age and as a result not as broken but in any event the depth of soil would lead to poor drainage.

Drainage history

Jim Leahy gave a history of land that was turned. There were a number of attempts to drain the field. A series of drains targeting wet areas were installed with grant aid initially and subsequently twice without grants with poor results. Jim observed that the second time he drained the field he used limestone chips which he deemed a “disaster” as the acid in the soil melted the limestone into a block.

Turning technique

Using excavator to dig and then return soil to same place on its side with organic topsoil not completely buried, A genuine attempt was made to combine the fertility of the topsoil with the bearing capacity of the subsoil more mixed than landed upside down(this allowed for mixing when harrowed), a small but crucial detail . The field was graded to give a fall into the drains. Leave for sun to dry it out, then disc harrowed and power harrowed. Two drains were installed to tap into wet patches (springs).

General observations

- Shale’s in Sligo and Leitrim tend to be deeper than Munster shale’s.
- Depth of shale rock itself important. If limestone underneath this will affect hydrology.
- Rainfall in Dublin 700mm, 500mm evaporation(in summer months peaking with solar cycle), 200 mm surplus.
- Rainfall in Athea 1500mm, 500mm evaporation, 1000 mm surplus
- Mixing on higher hills where you have iron pans at 300mm to a max of 1metre and the pan is broken can be very successful. This can be achieved by deep ploughing, turning or ripping.
- Mixing peat and mud is not as successful and rarely lasts more than 3 – 5 years.
- In some circumstances the 3 cut silage system on un-drained well fertilized ryegrass swards as practised in Kilmaley for many years should be considered. A variation of this was (carried out in Ballinamore) the use of Italian ryegrass for earlier silage.
- Could suit mole drains but because of silt gravel moles would be best.

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Picture 2 Naked mole installed at 450 mm

Picture 3 View of mole

Picture 4 Mole plough used

The mole plough used was found to be inadequate. The basic principles of mole drainage dictate that the trailing expander behind the mole foot be approx 1.1-1.2 times the diameter of the foot. The action of the mole foot creates the channel as well as initiating a network of cracks from the tip of the mole. The role of the expander is to finish and solidify the channel walls by bring about plastic deformation of the walls of the newly opened channel.

Mole drains are formed with a mole plough comprised of a torpedo-like cylindrical foot attached to a narrow leg, followed by a **slightly larger** diameter cylindrical expander. The foot and trailing expander form the mole channel while the leg creates a narrow slot that extends from the soil surface down to the mole channel depth. The success of mole drainage depends on the formation of cracks in the soil that radiate from the tip of the mole plough foot at shallow depths as the soil is displaced forwards, sideways and upwards at an angle of approximately 45° to the horizontal Below a critical depth, dependent on soil mechanical strength and mole plough geometry, the soil flows forwards and sideways, inducing plastic deformation at the foot of the plough. The action of the mole plough creates both a zone of increased hydraulic conductivity adjacent to the mole leg (shallower depths) and a channel for water conveyance and outflow at moling depth, when the soil is sufficiently plastic.

There was a view that John’s Mole plough wasn’t acting as a mole plough at all. The expander diameter was approx 3 times that of the mole foot (12cm vs.

4cm). As such when the mole was in operation the channel formed by the foot was negligible in comparison to the expander. This has a number of undesirable results.

- The expander is in effect forming the channel, which then doesn't undergo any further deformation and is likely to be unstable/poorly formed
- The expander is closing any cracks formed by the foot and causing negligible cracking of its own accord due to short length and poorly defined leading edge
- The draw bar pull increases with the square of the diameter(a 12cm mole needs 9 times the pulling power as a 4cm mole ,144/16=9 times, not 3). This is illustrated by the tracks left in the moled plot, the top sod simply couldn't provide the traction required, even if dry, traction with this mole plough would be an issue. Coupled with this the poorly defined leading edge of the expander and the result is moles being bludgeoned into place. This goes against all the mechanical and hydrological changes that one tries to induce in the soil when moling.

Soil profile of paddock 17

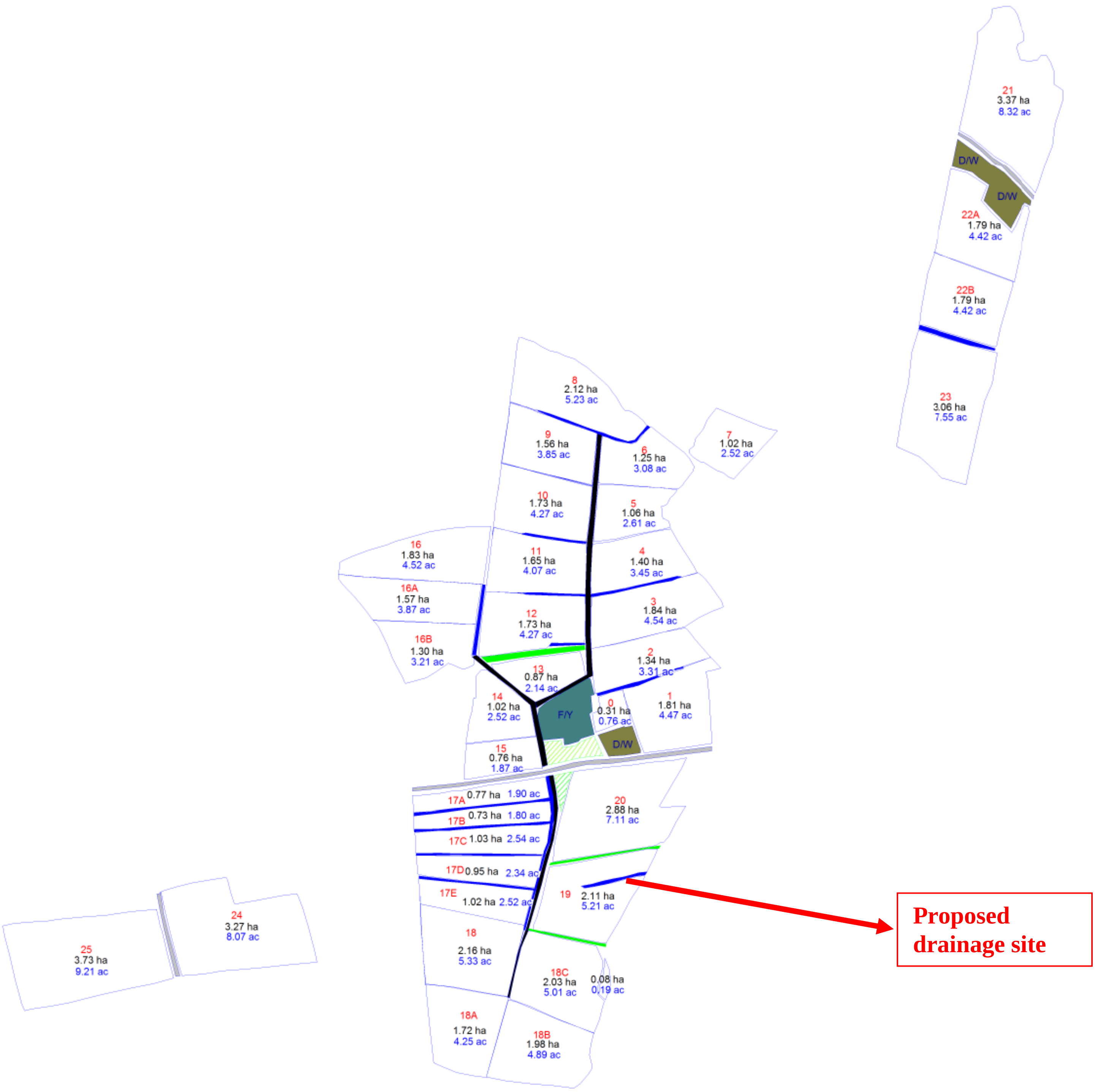
Depth cm	Description
0 - 46	Peat top soil, formerly deep ploughed, poor mineral mix in blobs through it. Weak and wet.
46 - 56	Transition loosish organic peat, mineral gley, low density, root channels, an iron concentration
56 - 75	Carboniferous clay till, relatively boulder free. Firm.
75 - 150	Less cemented upper carboniferous shale, silty clay loam. Wetter than paddock 19 not as compacted
1500- 320	Blue grey, sandy clay, stonier, less cohesive. Possibly limestone influence?

Soil profile of paddock 19

Depth cm	Description
0 - 30	Very organic on top half to organic on bottom. Mineral on bottom 150 mm. Limed causing peat to be less raw.
30 – 41	Transition loosish organic peat, mineral gley, low density, root channels, an iron concentration
41 - 52	Same as above but with less roots and less peaty`. Upper water table meeting oxygen. Loosish.
52 - 75	Carboniferous clay till, relatively boulder free. Firm.
75 - 150	Same as above but less cemented
150 - 200	Less cemented upper carboniferous shale, silty clay loam
200 - 290	Blue grey, sandy clay, stonier, less cohesive. Possibly limestone influence??
290 - 340	Lens of dark lignite type material. Possibly Emian, most likely a buried bog from 8,000 – 9,000 years ago

Provisional recommendations

The safest system for Athea would be gravel mole drains at a depth of 450 – 470 mm with collector drains at 15 metres to a max of 20 metres apart at a cost of €600 - €800/acre for moles and collector drains costing €600 - €800 /ac total €1200 -€1600/acre with a life expectancy of 30 – 40 years (naked moles on the other hand will last form 2 – 5 years). There will always be a benefit in deep ripping for mole drains as it improves the permeability. Deep ripping ideally should be carried out pre-moling at twice the density (half the spacing) and twice the depth of proposed moling.
There is pencil gravel available locally (see below) which is screened and relatively cheap which could be suitable for collector drains.


21 3.37 ha 8.32 ac
D/W
D/W
22A 1.79 ha 4.42 ac
22B 1.79 ha 4.42 ac
23 3.06 ha 7.55 ac
8 2.12 ha 5.23 ac
9 1.56 ha 3.85 ac
6 1.25 ha 3.08 ac
7 1.02 ha 2.52 ac
10 1.73 ha 4.27 ac
5 1.06 ha 2.61 ac
16 1.83 ha 4.52 ac
11 1.65 ha 4.07 ac
4 1.40 ha 3.45 ac
16A 1.57 ha 3.87 ac
12 1.73 ha 4.27 ac
3 1.84 ha 4.54 ac
16B 1.30 ha 3.21 ac
13 0.87 ha 2.14 ac
2 1.34 ha 3.31 ac
14 1.02 ha 2.52 ac
F/Y
0 0.31 ha 0.76 ac
1 1.81 ha 4.47 ac
D/W
15 0.76 ha 1.87 ac
17A 0.77 ha 1.90 ac
17B 0.73 ha 1.80 ac
17C 1.03 ha 2.54 ac
17D 0.95 ha 2.34 ac
17E 1.02 ha 2.52 ac
20 2.88 ha 7.11 ac
19 2.11 ha 5.21 ac
Proposed drainage site
24 3.27 ha 8.07 ac
25 3.73 ha 9.21 ac
18 2.16 ha 5.33 ac
18C 2.03 ha 5.01 ac
0.08 ha 0.19 ac
18A 1.72 ha 4.25 ac
18B 1.98 ha 4.89 ac

2.3 Tom and TJ Ryan, Rossmore, Co. Tipperary

Father and son partnership farm this heavy mineral soil, the home farm is quite flat with 62 cows on 36 Ha owned and 14 ha rented. They plan to expand to 75 cows.

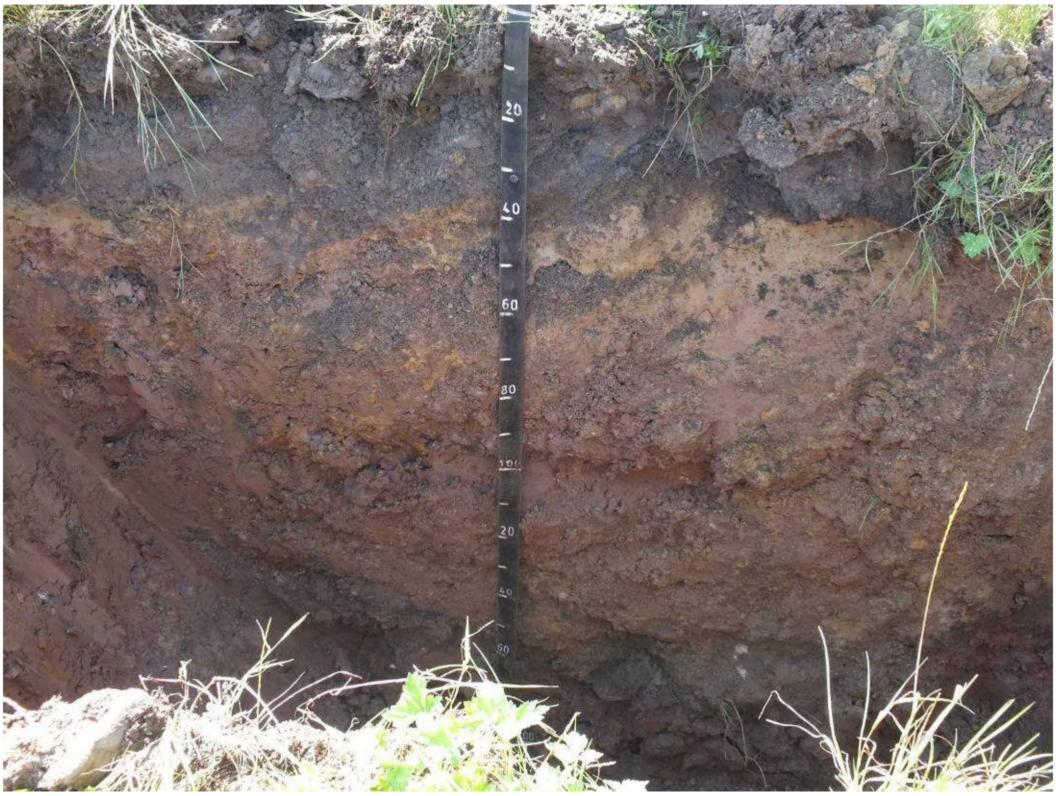
Farm visit took place on Thursday 23rd August 2012.

General Observations

- Farm is 100 metres above sea level
- Soil unusually loose. Normally at 3 metres the over burden weight consolidates the soil but on test holes on the farm it is loose which is probably to do with the way the soil was deposited.
- Conventional drainage carried out locally consists of drains a metre deep filled with stone (usually pencil gravel).
- Deep drains at 1.8 – 2 metres in depth with 0.2 metre of stone and a spacing of 15 metres could work well on this site.
- Trenchers and suitable digger buckets not freely available in Ireland. It is important to investigate sources. It may be necessary to have a suitable bucket manufactured.
- The Ryan farm reflects a lot of wet land in the country that is not Carboniferous Shale.

- 40 ha milking platform, planning to go from 50 to 80 cows. There is enough winter feed conserved, though locally only 50% silage made. Conservative approach to grazing (cows housed when ground conditions are poor).

Test Hole 1



Depth cm	Description
0 - 10	Silty clay topsoil, darkish organic material
10 - 20	Light grey, reduced iron layer. Fen mottles, some stone, sandy clay loam
20 - 40	Medium grey, silty clay loam, signs of root cracking, fairly stone free, suggests water sorted
40 - 50	Very light orange, water separated (glacial stream separated) sand, could be glacial outwash.
50 - 130	Typical old red sandstone – till, some rounded stones, signs of rooting to 130, clay skinned surface, natural cracks. Clay loam.
130 - 240	Slightly sandier, sandy clay loam, softer with seepage through this layer with sand lenses, good cracking to 1600

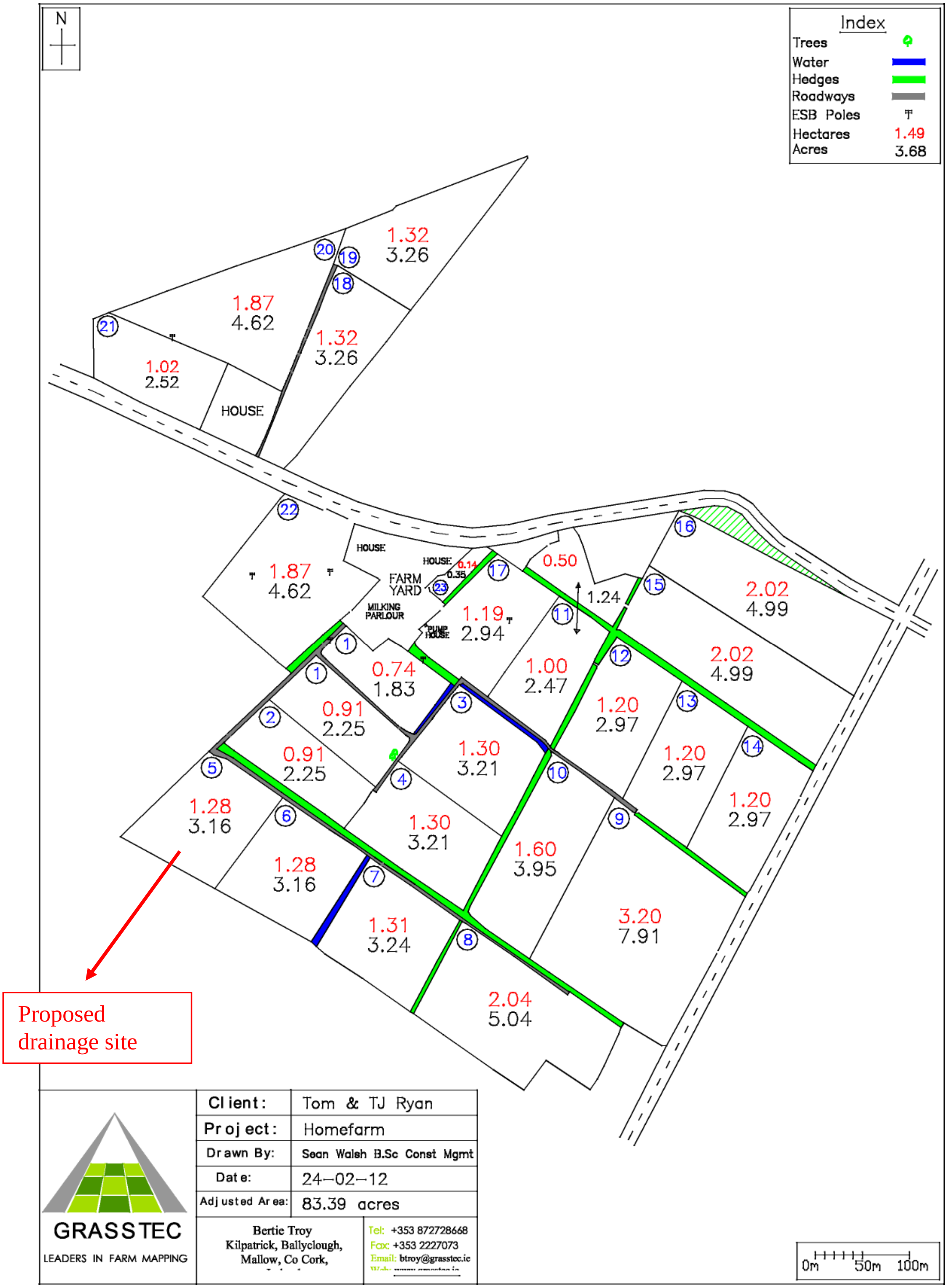
It can be seen from picture above that there was quite an amount of subsidence in the test hole. This continued for the period while we were on the visit.

Test hole 1 after 12 hours

Test Hole 2

Test hole two uncovered a very similar soil profile to that of test hole one and as such the soil profile of test hole two is considered to match that of test hole one (description above).

Picture above shows field that was re-seeded last year. Open water courses were cleaned and it was re- fenced.


N
Index
Trees
Water
Hedges
Roadways
ESB Poles
Hectares 1.49
Acres 3.68
1.32
3.26
1.87
4.62
1.32
3.26
1.02
2.52
HOUSE
1.87
4.62
HOUSE
HOUSE
0.14
0.35
FARM YARD
MILKING PARLOUR
PUMP HOUSE
0.50
1.24
1.19
2.94
2.02
4.99
2.02
4.99
0.74
1.83
1.00
2.47
1.20
2.97
0.91
2.25
1.30
3.21
1.20
2.97
0.91
2.25
1.20
2.97
1.28
3.16
1.30
3.21
1.28
3.16
1.60
3.95
1.31
3.24
3.20
7.91
2.04
5.04
Proposed drainage site
Client: Tom & TJ Ryan
Project: Homefarm
Drawn By: Sean Walsh B.Sc Const Mgmt
Date: 24-02-12
Adjusted Area: 83.39 acres
GRASSTEC
LEADERS IN FARM MAPPING
Bertie Troy
Kilpatrick, Ballyclough,
Mallow, Co Cork,
Tel: +353 872728668
Fax: +353 2227073
Email: btroy@grasstec.ie
0m 50m 100m

*2.*4 Michael & Donal Keane, Drumurrin, Lisselton, Listowel, Co. Kerry

This farm has a peat soil and is run as a father and son partnership. The farm business has been expanding, currently milking 75 cows with plans to increase to 100 cows on a 52 Ha farm in two blocks. The farm visit which took place on Friday 30th March 2012 concentrated on the milking platform which is 37 Ha. In 2011 four hectares in this block was drained and re-seeded at a cost of €16,000.

Tim Gleeson has extensive experience of cut away peat and has worked with Bord na Mona on successfully draining hundreds of acres of bog. It should be noted that while there are some similarities with the mid-lands there are also significant differences such as a much higher rainfall in Listowel (1,350mm in 2011) and a narrower band of permeable material in Listowel which will impact on recommendations for drainage.

Two test holes were dug on the day and on the previous day two other holes were dug and back filled immediately (for safety reasons) which were very similar in appearance to what will be described.

Test hole 1 in paddock 35

Test hole 1 was opened to a depth of 160 cm the previous afternoon. And left open overnight, water was visible at base of the pit in the morning.

Depth cm	Description
0 - 60	Woody fen peat of blanket peat origin
60 - 90	Weathered gravelly silt with root penetration
90 - 110	Slightly weathered gravelly silt some root penetration. Pit walls becoming increasingly unstable.
110- 180	Medium consolidated stony, gravelly silt
180 - 250	Loose (ish) gravelly silt
250 - 320	Bit less permeable more consolidated
320	Gravelly silt. High water ingress noted at base of pit.

Test hole 1 at 3.2 metres deep

Test hole 2 in paddock 26

Depth cm	Description
0 - 70	Woody fen peat of blanket peat origin
70 - 90	Silt with clay, slight weathering, some root penetration
90 - 110	Silt with little clay, very few stones
110 - 150	First permeable layer. Low rate of seepage noted, sides of pit unstable.
150 - 180	Clayey silt with gravel
180 - 260	Less permeable more clay
260 - 300	Lower permeable layer gravelly, clayey silt. Moderate to high water ingress noted from base of pit.

Test hole 2 at 3 metres deep

Two soil cores were taken at different locations in paddock 35

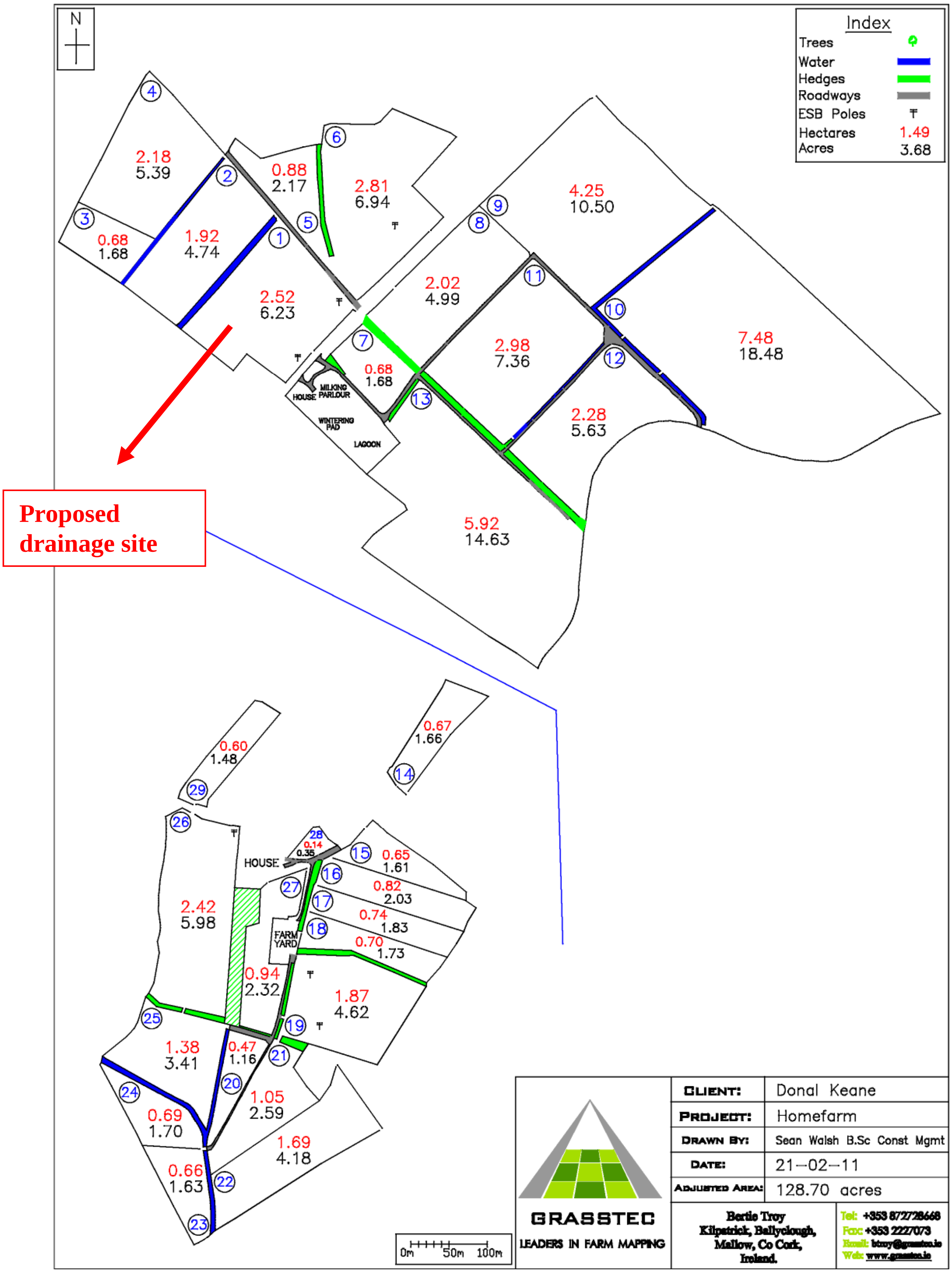
Soil core 1

Depth cm	Description
0 – 10	Organic mineral soil
10 – 30	Humified peat
30 – 60	Peat with decomposed timber, browner in colour
60 – 90	Getting wetter and greasy, still with some timber
90 - 100	Grey mineral with some peat

Soil core 2

Depth cm	Description
0 - 20	Greasy wet peat
20 - 70	Brown porous peat with some timber roots
70 - 110	Grey mineral getting stony
110	Increasing gravel content with grey

Recommendations based on findings above (acknowledging that more test holes would need to be dug and that the early drains to be installed would also inform depth and spacing requirements) are for deep drains at 15 metre spacing at an approximate cost of €2,500/ac.


Proposed drainage site
N
Index
Trees
Water
Hedges
Roadways
ESB Poles
Hectares 1.49
Acres 3.68
2.18
5.39
0.68
1.68
1.92
4.74
0.88
2.17
2.81
6.94
2.52
6.23
4.25
10.50
2.02
4.99
2.98
7.36
7.48
18.48
0.68
1.68
2.28
5.63
5.92
14.63
HOUSE
MILKING PARLOUR
WINTERING PAD
LAGOON
0.60
1.48
0.67
1.66
HOUSE
0.14
0.35
0.65
1.61
0.82
2.03
0.74
1.83
0.70
1.73
FARM YARD
2.42
5.98
0.94
2.32
1.87
4.62
1.38
3.41
0.47
1.16
1.05
2.59
0.69
1.70
1.69
4.18
0.66
1.63
0m 50m 100m
GRASSTEC
LEADERS IN FARM MAPPING
CLIENT: Donal Keane
PROJECT: Homefarm
DRAWN BY: Sean Walsh B.Sc Const Mgmt
DATE: 21--02--11
ADJUSTED AREA: 128.70 acres
Bertie Troy
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Mallow, Co Cork,
Ireland.
Tel: +353 872728668
Fax: +353 227073
Email: btroy@grasstec.ie
Web: www.grasstec.ie

2.5. John O'Sullivan, Ballingree, Castleisland, Co. Kerry

Picture 1: General view of farm

John inherited the farm from his late father who purchased it in the late 1960's. The 71 Ha holding (20 Ha long term lease) has a heavy clay soil with good depth but poor permeability. There are 82 cows milking with plans to expand to 120 cows. Visit took place on Wednesday 30th May 2012.

The picture above gives a view of the terrain (John and his son in picture). John has a long term lease on an adjoining farm on which he has built roadways and re-seeded pastures.

Drainage History

Over the years drainage work was done on the farm, most likely grant aided under the land project scheme as there was evidence of drainage pipes with concrete at the outlets going into open drains John O'Sullivan observed that there was rarely water evident in these drains

General observations

- On this farm soils range from brown earth, to grey, to loamy silt soil to rock appearing over-ground.
- Annual rainfall 1500mm
- Sink holes occur at various points around the farm. They can drain very well for a few years but can then block up, with another one appearing

in a different location. They can be used to drain into but with a caution that the may not drain as much as might be expected and that they may block up in time.

- The farm is on Carboniferous shale over Karstic limestone.
- Main problem rainfall not draining way quickly enough which suggests that deep drains would not be appropriate.

Picture 2: Soil profile Paddock 21

Depth cm	Description
0 - 25	Top soil organic silty clay loam, poor structure (sub-angular)
25 - 65	Silty clay loam, grey layer, no structure
65 - 130	Silty clay loam, highly mottled
130 - 280	Increase in small stone, quite cemented, more gravel, more brittle

Picture 3: Shallow pit paddock 7

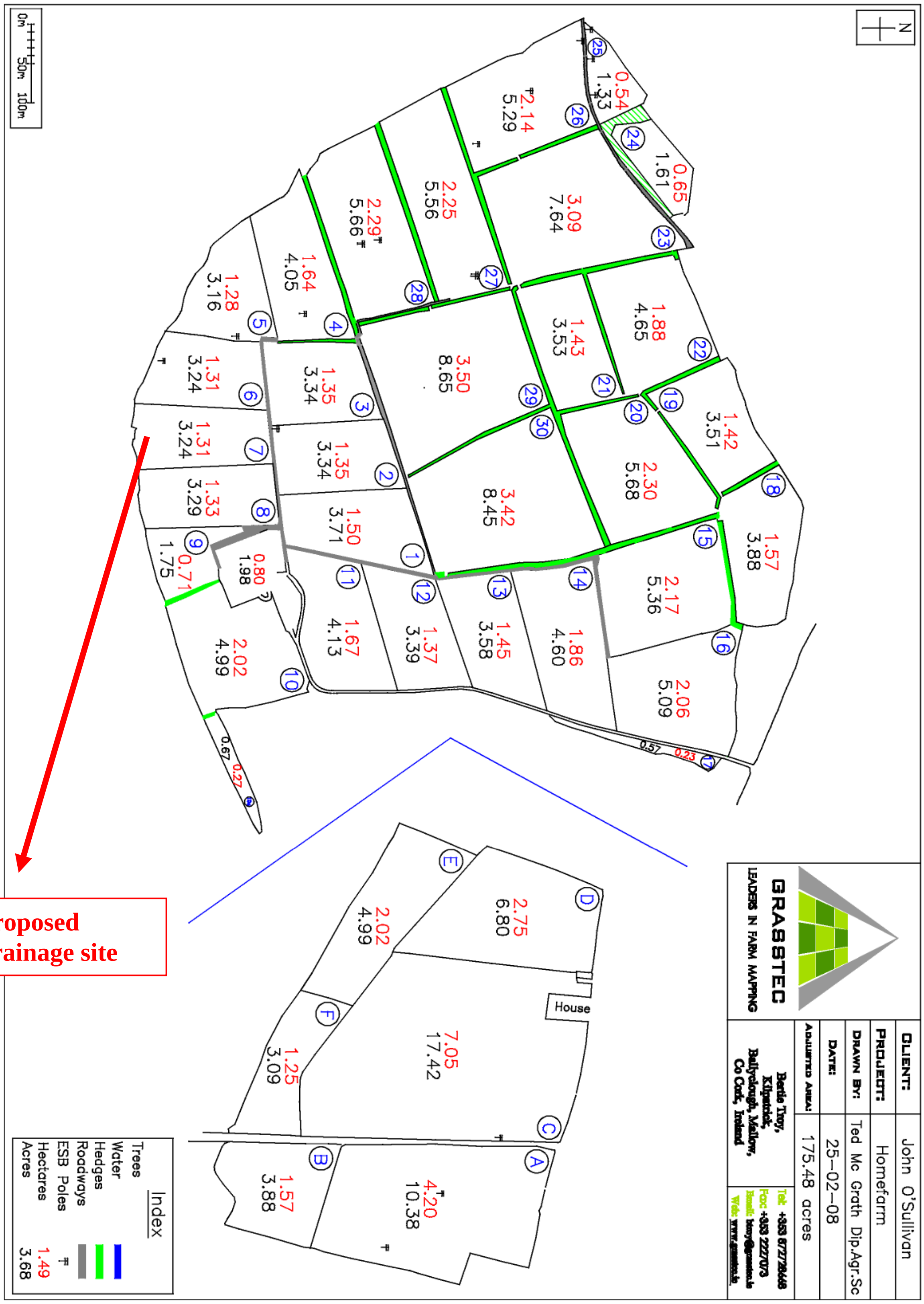
Depth cm	Description
0 - 40	Top soil brown, some rusty mottling. Finer structure, moderate granular
40 - 90	Silty loam to clay loam,
90 - 165	Silty clay loam, cemented, more small stone

Picture 3: Deep pit paddock 7

Depth cm	Description
0 - 30	Top soil dark brown, coarse blocky weak structure
30- 90	Stones 10 – 20 cm through it. Weak blocky structure, white to cream in colour
90 – 160	Silty clay loam, highly mottled, fair stone content, compact
160 – 360	Increase in small stone, quite cemented, more gravel, more brittle

Provisional recommendations

Naked moles would be worth a try; however the best option would be gravel mole drains at a depth of 450 – 470 mm. The deluxe version would be deep ripping at 600 mm with gravel moles installed in every second rip.



Proposed drainage site

2.6. Con Lehane, Ballinagree, Macroom, Co. Cork

Con took over the running of the farm from his father Neilus a few years ago. The farm has a heavy clay soil with poor permeability and is quite stony in places. There are 80 cows milking on 69 Ha (13 Ha on a long term lease) with plans to expand to at least 100 cows. Visit took place on Tuesday 12th June 2012.

Picture 1: John Maher, Tim Gleeson, Pat Tuohy and Neilus Lehane

Drainage / Reclamation History

Over the years a lot of deep drains were installed. Drainage work done involved digging drains up to 5 metres deep. Small stones were put in the bottom of the drain and then filled up to the top with boulders that were on the surface or were raised when digging the drains. This was pain staking work as the large boulders were shunted one by one into the drains with a tractor.

Higher up the farm there was strategic installation of shallower drains to tap particularly wet areas and the soil was turned to mix the peaty top layer with the sub-soil which resulted in a much firmer soil. The positive effects of this turning would last up to ten years.

General Observations

- Farm at an altitude varying from 150 – 300 metres (550 – 1000 feet) above sea level.
- 1500 – 1600 mm rainfall annually
- Drainage on the farm has to allow for the higher rainfall, colder temperatures and the related formation of poorly drained soils associated with its altitude.
- Glacial drift North Kerry glacation age, bouldery glacial drift.
- Sub – soil map shows mostly old red sandstone.
- Top of the farm is cut away bog, before it was harvested (many years ago) there would have been 2 – 2.5 metres of turf.

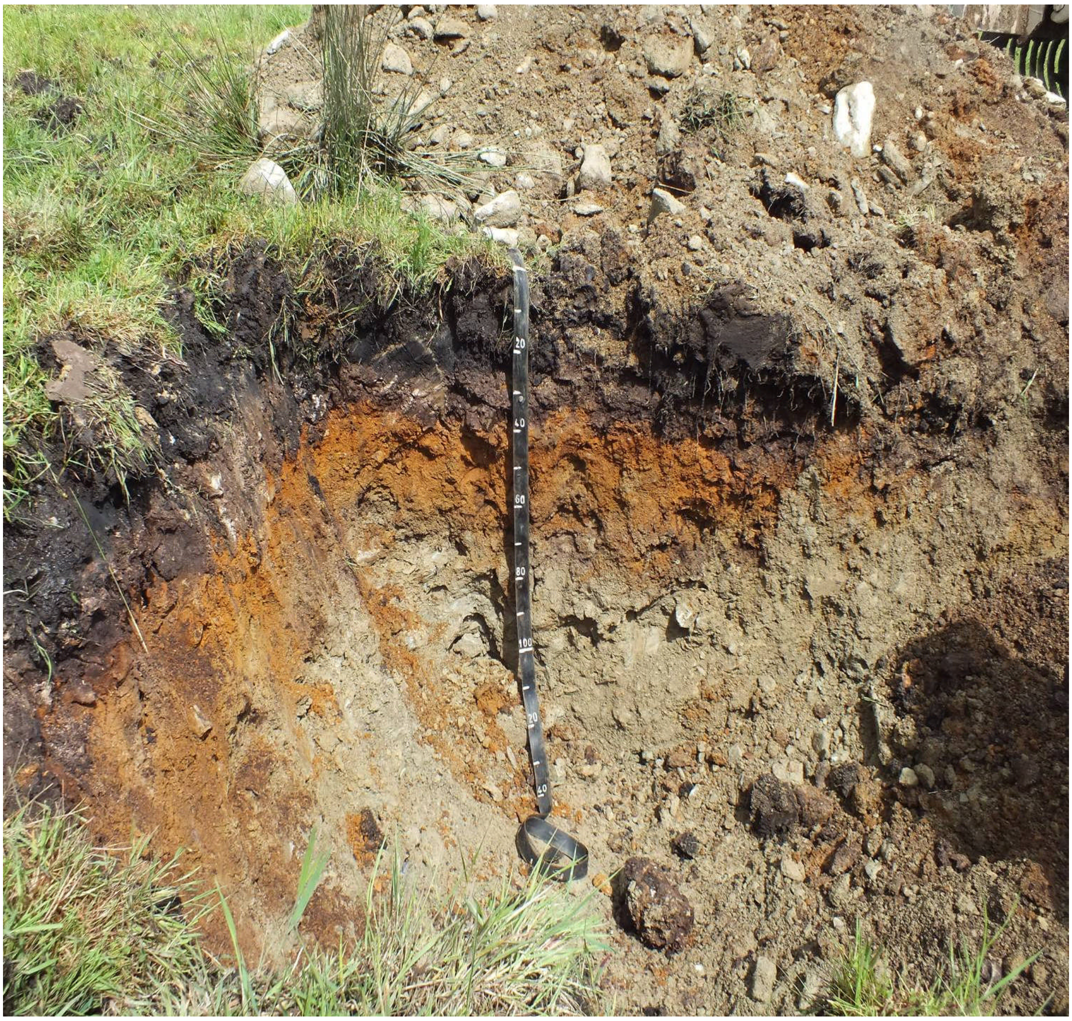
Test Hole 1 in Paddock 12

Depth cm	Description
0 - 20	Dark brown, organic, silty clay loam
20 - 35	Gravelly, stony layer
35 - 70	Fairly tight gley, very gritty silty clay loam
70 - 140	Iron depositions with some manganese concretions increasing at 1200 - 1300
140 - 280	Stony, gritty, gravelly silty clay loam going on to silty clay with lots of cobble type material. Seepage visible at 1500. Getting quite bouldery at 2700
280	Bedrock

Test Hole 2 Peat turned site in Paddock 19

Depth cm	Description
0 - 50	Original peat very soft dark organic material, mixed with mineral material
70 - 80	Gley, silty clay loam, quite gritty
80 - 150	Low porosity, fairly dense, very gritty and silty.
150- 290	Stony, gritty, gravelly silty clay loam going on to silty clay with lots of cobble type material. More boulders than Test Hole 1.

Test Hole 3 in Paddock 19



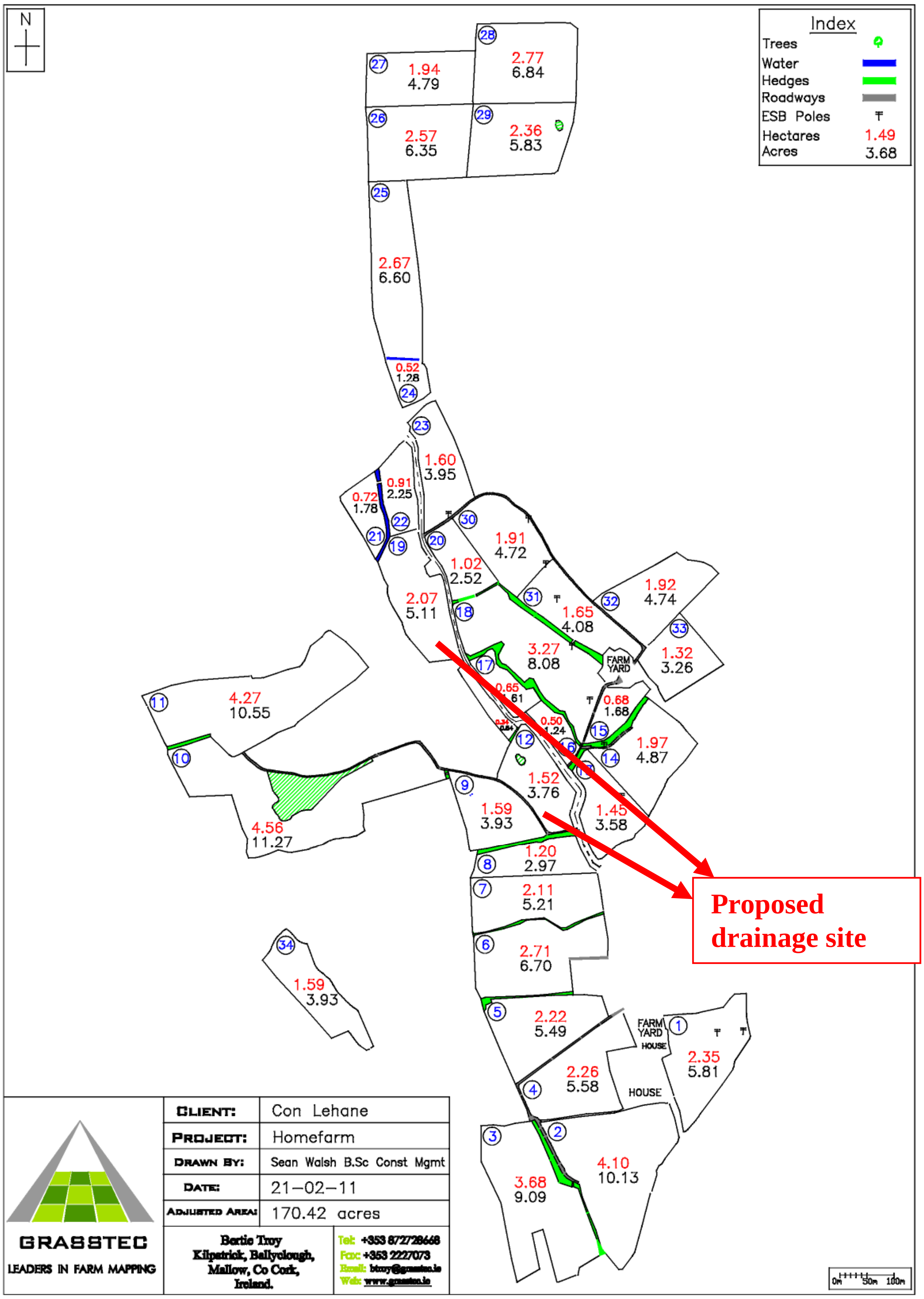
Depth mm	Description
0 - 300	Peat reforming again after being turned in the past (probably done with a ripper).
300 - 600	Very brown loosened podzol reforming with a reforming iron pan at 300mm
600 - 1500	Meeting rock at 1500mm which is probably fissured as the soil over it is dry.

Ripping was carried out approximately 10 years ago; this operation would have shattered the iron pan and allowed movement of water through the profile. The area is now reverting to its wet state with a lot of surface water/poaching. The test hole shows signs of reformation of an iron pan, and resulting reformation of peat. The formation of an iron pan is encouraged where acid soil conditions prevail, thus the addition of lime may slow or stop altogether the reformation of a pan if ripped again?

Picture 2 (above) shows field where test hole 3 was dug (paddock 19). The green field in the background is the highest point of the farm at 300 meters.

Picture 3 which was taken in Paddock 19 is an example of the type of drains that were installed on the farm. The large stones that can be seen around the tape were used to fill the drain. There was a very good flow of water in this drain.

Picture 4 below shows the outlet from this drain into an open water course.


N
Index
Trees
Water
Hedges
Roadways
ESB Poles
Hectares 1.49
Acres 3.68
Proposed drainage site
FARM YARD
HOUSE
CLIENT: Con Lehane
PROJECT: Homefarm
DRAWN BY: Sean Walsh B.Sc Const Mgmt
DATE: 21–02–11
ADJUSTED AREA: 170.42 acres
GRASSTEC
LEADERS IN FARM MAPPING
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Mallow, Co Cork,
Ireland.
Tel: +353 872728668
Fax: +353 222707
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2.7 Sean O'Riordan, Knochnenaught, Kiskeam, Co Cork

This farm has a mix of free draining soil well developed and maintained (50%) and recently acquired heavy clay soil with poor permeability. There is a requirement for substantial development work to be completed on the farm. This farm is characterised by steep hills. There are 75 cows milking with plans expand to 100 cows on 50 Ha.

Farm visit took place on Wednesday 15th August 2012. Picture below shows an overview of some of Sean's farm. Test holes 1 and 2 were dug on top of the hill behind row of trees at top right of picture. Test hole 3 was dug 50 meters right of the bottom right hand side of picture.

General Observations

- Rainfall 1490 in 2011, 1,000mm this year to date (mid-August 2012)
- Locally this type of land would be ploughed regularly at a depth of 200 – 225 mm to improve drainage.
- Deep ripping at a depth of 1150mm an option for land typical of test hole 1.
- Deep drains might also have a role to play.
- Farm on Upper Carboniferous shale.
- Gravel moling on soils with peat topsoil is not as successful as soils with mineral topsoil as the cracking achieved in the ploughing is not maintained in the peat.
- There is an argument in some cases for combining deep drains with gravel mole drains, particularly if seepage is an issue, however thought must be given to the combination of costs

- P and K indices are very low on the farm.
- The more radical drainage option in the field where the first holes were dug would be installing sumps to the depth of the highly receptive drainage layer uncovered in test hole one and running trench drains from the higher parts of the field down to these sumps. It is something we should discuss,, especially considering the inflow levels on the night of the 14th to test hole one. This would be classed more as a percolation system with the main issue being whether the water would re-emerge somewhere downhill,
- The flow from the three drains in the last field we were in (near test hole 3), indicates quite a good level of seepage into these drains at quite a shallow depth, something not uncovered by the(quickly dug) test pit in this area. (Although it could be argued that surface flow was contributing, particularly on the day in question). Drains similar to these with some help from moles or gravel moles in poorly permeable areas could be a staring point for this area.

General discussion

A good discussion on the important issues facing Sean O'Riordan took place. The key areas where guidance was needed were:

- Remedial action (if any) to repair poaching damage done this year
- The most appropriate drainage solutions for the farm
- The livestock carrying potential of the farm which allows for a wet summer like 2012.
- Winter forage situation. Not enough silage conserved and a lot of silage fed back over the summer
- Lower milk solids output and profitability due to feeding silage and concentrate during the main grazing season because of difficult grazing conditions and low grass growth.

Test Hole 1

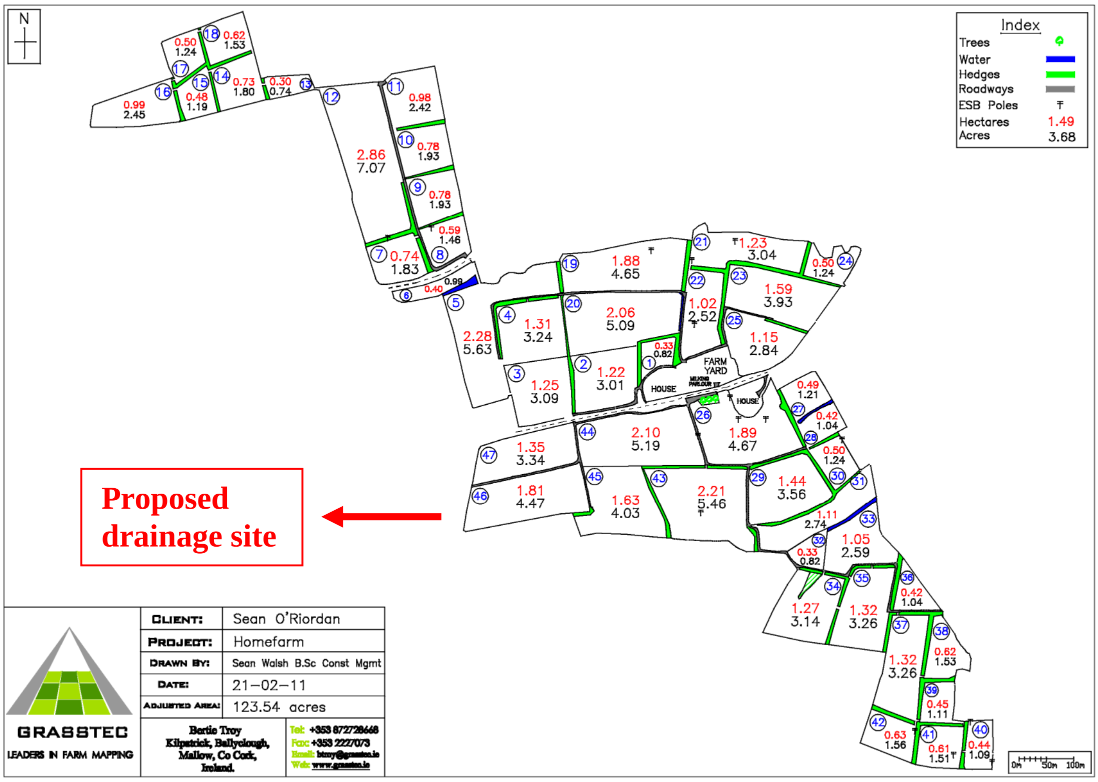
Depth cm	Description
0 - 30	Peaty top soil
30 - 45	Yellowish layer, gritty clay/silty loam
45 - 155	Clay loam, increasing concentration of stones, high pebble content
155 - 200	Permeable shattered shale with large ingress of water
200 - 250	Less permeable shale, less shattered, close to bed rock

Test Hole 2

Depth cm	Description
0 - 25	Peaty top soil
25 - 50	Silty clay loam
50 - 80	Clay loam, increasing concentration of stones, high pebble content
80	Bedrock

Test Hole 3

Depth cm	Description
0 - 25	Top soil highly organic (peaty)
25 - 30	Compact leeched layer
30 - 60	Yellowish red silty loam of the podzol type. Where red not present grey in colour, reasonably compact
60 - 350	Little looser, stony, reasonably compact, water table visible at approx 3400 after 35 minutes



N
Index
Trees
Water
Hedges
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ESB Poles
Hectares 1.49
Acres 3.68
Proposed drainage site
FARM YARD
HOUSE
HOUSE
CLIENT: Sean O'Riordan
PROJECT: Homefarm
DRAWN BY: Sean Walsh B.Sc Const Mgmt
DATE: 21–02–11
ADJUSTED AREA: 123.54 acres
GRASSTEC
LEADERS IN FARM MAPPING

Business Plans

Business plans will be drawn up for each farm working closely with the farmers involved. Most of the ground work is done; the final piece of the jig saw will be the drainage costs which will now be calculated. These plans will form the basis of the expansion they plan and the land improvements and drainage proposals will be subject to rigorous cost benefit analysis.

2011 Data

Data collected are 2011 is shown below. Table 1 shows an average herd size of 88 cows with a Protein % 3.41 and Butter Fat % 3.88. The average herd size of these farms in 2006 was 67 cows. The farmers have been buying milk quota over the years and gradually building cow numbers. The total cost per litre for the heavy soils farms was 20.1 cents, this compares with a cost of 19.13 c/litre for monitor farms in the Kerry Agribusiness programme on dry soils, however the total costs of milk production recorded on the farms in the heavy soils programme was less than the national average recorded through the Teagasc Profit Monitor by 1 cent per litre.

Table 1: Performance of herds on Heavy Soils Programme 2011

	Cows	Total Production litres	% Protein	% Fat	SCC	Total costs c/l	Milk price c/l
Castleisland	95	534978	3.36	3.77	255	19	34.2
Doonbeg	84	428516	3.48	3.96	244	23.2	35.5
Listowel	80	453810	3.47	3.91	272	18.4	35.3
West Limerick	86	402199	3.39	3.96	260	22.6	35.0
Macroom	83	510198	3.34	3.75	210	17.6	36.3
North Cork	93	423967	3.42	3.91	331	19.7	34.8
Average	88	458945	3.41	3.88	262	20.1	35.0

Table 2 shows an average stocking rate of 2.10 Lu/Ha on the heavy soils farms compared to 2.46Lu/Ha on the Kerry Agribusiness monitor farms on dry soils. It should be noted that the Castleisland and West Limerick farms rear their replacements on the milking block; the other farms use an outside farm to rear replacements.

Table 2: Milk Supplies 2011

Farm	Cows No.	Milking Block (ha)	M Block SR LU/ha	Farm MS kg	MS/ cow	MS/ Ha	Conc. fed kg
Castleisland	95	51.1	2.28	37730	447	1010	771
Doonbeg	84	41.5	1.72	31842	406	699	467
Listowel	80	28.3	2.79	33116	437	1120	775
West Limerick	86	52.7	1.57	30108	367	578	571
Macroom	83	45.0	1.84	37310	449	829	770
North Cork	93	42.9	2.53	31292	352	890	380
Average	88	43	2.10	32817	410	872	593

Table 3 shows the grass production data recorded weekly by the participating farmers on a web based farm package. There was on average 7.72tonnes/ha of grass dry matter utilized compared to 9.7 on the Kerry Agribusiness monitor farms on dry soils, however the amount of grass utilized per hectare on the farms in the heavy soils programme was more than the national average recorded through the Teagasc Profit Monitor by about 0.5 tonnes/Ha. The dry farms on the Kerry Agribusiness programme produced 36,158 kg of milk solids, 345 kg/cow, 945 kg /ha.

Table 3: Grass Production 2011

	***Grass growth (t/ha) 2011***				
	Date start	***Date last***	***Farm Walks***	***Grazing area***	***Tonnes/ha utilized***
Castleisland	11-Feb	23-Nov	42	51.1	8.8
Doonbeg	02-Mar	25-Nov	38	41.5	6.9
West Limerick	15-Jun	28-Nov	24	52.7	6.3
North Cork	01-Apr	-5-Nov	32	42.9	7.5
Average	5/4/11	11/11/11	30	43	7.72

Table 4 shows the average ryegrass ground cover on the farms is 26%, on monitor farms on well drained land ryegrass cover is at 50% A two year old reseed well managed and fertilized could have a cover of 70% – 80%; a poor old permanent pasture could be as low as 3%. Establishing and maintaining ryegrass in heavy soils is challenging. The level of reseeding among the participants is encouraging.

Table 4: Ryegrass ground cover and level of reseeding

Region	***% Ryegrass***	***Level of reseeding annually (%)***
Castleisland	24	10
Doonbeg	30	10
Tipperary	28	15
Listowel	25	10
West Limerick	26	7
Macroom	25	10
North Cork	24	9

Table 5 shows the soil fertility results. National data from Johnstown Castle for 2010/2011 show that 60% of the country has a pH level of less than 6 and for both P and K 50% of the samples were in index 1 and 2. The Heavy Soils Farms were all deficient in lime and had varying levels of P and K. It is clear that there are major challenges and costs involved in improving these results.

Table 5: Percentage farm deficient in nutrient			
	pH<6.0	***P < index 3***	***K < index 3***
Castleisland	84	53	0
Doonbeg	80	30	40
Macroom	91	35	35
Listowel	90	0	70
Tipperary	100	66	75
Athea	75	64	58
North Cork	75	92	50
Average	85	53	47

Cost of the poor 2012 weather conditions

2012 is proving to be the perfect storm for anyone farming on heavy soils. The incessant heavy rain is impacting on growth but even more so on grass utilisation. Combine this with compromised animal performance due to poorer quality grass and it really starts to attack the bottom line.

The effect of poor growth in April and May and the deteriorating ground conditions from late June to the end of August has added an average of 21 tonnes of meal and about 10 tonnes of silage Dry Matter (DM) to be fed on the Heavy Soils Programme farms. With meal costing around €300 per tonne of DM and silage costing €170/tonne DM, the bill so far this year for extra feed is €7,966 per farm (21tonnes meal x €300 plus 9.8 tons silage x €170). This does not take account of income lost due to poorer yields and reduced milk constituents. There are potentially other costs looming for these farms as with silage stocks being eaten into it may leave winter fodder stocks low which may mean further meal or forage purchases will be needed. Also many of the farms will at this stage have used up the best quality silage which would normally be fed in late lactation to supplement grass. This year poorer quality feed may be all that is available which again will affect performance of cows and impact negatively on revenues and cash flow.

3 Farm Visits September/October 2012

Following on from site investigations which are reported above, each farm was visited over the last month to establish their drainage plans for the coming years. The response from the farmers was very encouraging, with each farmer willingly making available 2 Ha for trial purposes and also willing to co-fund the costs.

3.1 Michael & Donal Keane

- Visit on 24th Sept 2012.
- Cows on silage and meal by day standing in yard, on grass at night
- To complete work done on main grazing block an additional 2,500 – 3,000 metres of drains need to be installed cost €2.50/metre to dig, €2.75 for stone €18 - €20k to be spent.
- Disappointed with the performance of some deep drains which were water logged on the morning of our visit directly over the drains (after very heavy rain the previous night)
- An investment required for handling dirty water in lagoon. Pump, piping and sprinkler required. Could cost up to €20k
- Is there merit in using a water diviner to assist in deciding where drains should be installed,
- 5 acre field where we dug last test holes available for trial purposes.
- 12 acres near the bog classified as rough grazing. 1 hectare of this land was fenced off as a habitat under Reps 4. We need to check out if this land needs permit for drainage.
- Milk price will determine how much money will be available for investment. There are two families drawing from the farm.
- Some drains were installed with mud used as back fill over stones. The ground was very soft and messy at top of the drains with lots of surface water evident (there was heavy rain the previous night).

3.2 John Leahy

- Visit on 24th Sept 2012
- Cows housed at night for last 3 weeks on silage and meal, grazing by day.
- 3.5 acres turned this summer, this took 85 hours on the digger
- Land that was turned last year and re-seeded was firm under foot but almost no evidence of ryegrass.
- Soil fertility on turned land pH 5.1, P 0.373. Bagged lime used. Is there a role for rock phosphate and basic slag? Should ground limestone be used?
- Will we get Michael O'Donovan to visit farm?
- 5 acre field where we dug last test hole is available for trial work. It was deep ploughed in the past but has been left without any fertilizers for the last 6 years. It is now covered in rushes with little or no grass evident.
- John is concerned about the effectiveness of mole drains. Will they hold their shape? Is the layer they will be pulled through consistent enough?

- The turned ground is available for monitoring.
- Grass seed mixture for this type of land need to be re-examined

3.3 John O'Sullivan

- Visit on 26th Sept 2012
- Paddock 5 ploughed in 2008 by contractor 9" and re-seeded. It is a poor performer and poaches easily.
- Paddock 4 (beside P 5) was ploughed in 2011 by John to a depth of 6". It has performed well and hasn't poached badly. Both fields need 8 tonnes of lime per Ha and are at index 2 for P and index 3 for K
- Paddock 28 was re-seeded in 2010. It had been sprayed off, cultivated in perfect conditions and rolled after seeding, germination was good. It is now full of rushes, buttercup and weed grasses with very little rye grass evident. It is at index 2 for P, index 4 for K with a pH of 5.6. Paddock 27 was also re-seeded in 2010 but was not rolled after seeding; it is also full of rushes, weeds, etc. Both paddocks are relatively firm and are not badly poached.
- 2012 silage results for crop cut on 10/06/12 were 63 DMD.
- Paddock 7 is the paddock John would like to do some drainage work on. It is the paddock we dug the first test hole in when we were there in May 2012. Table 6 below shows Dry Matter production for the last two years.

Table 6: Seasonality and total DM production in 2011 and 2012

Year	Jan - Mar	Apr - Aug	Sep - Dec	Total
2011	0.3	6.4	2.9	9.7
2012	1.0	4.2	1.0	6.2

3.4 Sean O'Riordan

- Visit on 26th Sept 2012
- Farm has recovered significantly from the time of our visit in August and while poached has dried out and on half the farm ground conditions are reasonable.
- Winter feed deficit has been addressed by purchasing a load of soya hulls (24 tonnes) and selling some stock
- EBI report for herd was unchanged at €127 with €35 for milk
- Drainage proposals are for two adjoining fields of approx 1.6 Ha each below the milking parlour. These fields have been neglected in recent years and are overgrown with rushes. Sean remembers a time when silage was cut there by light tractors.

3.5 Danny Birmingham

- Visit on 8th October 2012
- 160 bales of silage fed to 88 cows during the summer
- Meal feeding 1 tonne per cow
- Cows housed for 30 nights
- Plan is to drain 10 acres every year
- Connacht Agri pipe drains do not seem to work as well as in previous years. Slurry was spread last year with a heavy tanker, Danny suspects it may have damaged some pipes.
- Would like an overall drainage plan for the farm.
- Paddock 29 available for trial work. It is a 5 acre field in the first block we dug a test hole in when we visited. It is a rectangular field with a road running along by it, with 3 entrances and 3 water troughs. There is very little ryegrass evident and this year Danny estimates that grass utilization was 50%.
- There is a one metre open drain running along the back of the field.
- Pencil gravel available on the farm

3.6 Tom & TJ Ryan

- Visit on 8th October 2012
- 3 kg of concentrate fed right through the grazing season expect to use 750 kg for the year
- Milk supply volume down slightly for the year. Currently 3.66% Protein and 4.44% Butterfat
- 5 acre field where we dug test holes available for trial work. It has good road access and a 2 meter drain running by. It has only been fertilized once this year (because of ground conditions) and grazed four times.
- The experience on the farm is that the shallow (0.7metre deep) are not very successful
- For re-seeding the Ryan’s prefer to plough rather than stitching.

3.7 Con Lehane

- Visit on 18th October 2012
- 4 kg of concentrate per cow per day fed since 1st July because of poor grass growth, normally feeds 1kg/day
- Carried over large reserve of silage from 2011 this covered half his silage requirements for 2012. This allowed him to free up silage ground for grazing in the first half of the year.
- On the grazing block the priority is to improve paddocks 12 and 19 which based on the evidence of the site investigations would involve different drainage solutions.

Lessons from Heavy Soils Project 2012

- Years with heavy rainfall impact negatively on costs and profit
- With the frequency of wet summers apparently increasing in recent times it highlights the need to have fodder reserves in place. These need to be built up in good years to help survive summers such as this. Providing for such additional fodder reserves will constrain stocking rates and thus potentially limit expansion on heavy soils.
- Maintaining good quality ryegrass swards is more difficult on heavy soils and appropriate varieties will be vital if more grass is to be grown and utilised on these farms. Developing strategies to minimise poaching will have to continue in order to maintain persistent/productive swards
- Like most other dairy farms nutrient status and pH of soils needs attention if expansion is planned
- Appropriate drainage systems based on site assessment will be a cornerstone of managing these farms.
- Ongoing development of farm infrastructure will be a crucial factor in grazing management on heavy soils

4. Principles of Land Drainage and Cost Benefit Analysis

The difficulties of drainage problems in Ireland are largely due to our complex geological and glacial history. Glacial processes lead to the formation of rolling and undulating landscapes, made up of haphazardly sorted rock and soil materials. Layers of varying texture and composition have the effect of irregularly distributing groundwater flow, with fine textured soils acting as a barrier to movement, impeding drainage, and lenses of gravels and sands promoting water flow, transmitting groundwater over large areas with resulting seepages and springs on lower ground.

The rate at which water moves through a soil, *hydraulic conductivity*, varies enormously depending on the soil type and management. Open gravelly soils have a capacity for water flow that is hundreds of thousands of times that of a compacted heavy clay. In free draining soils the rate at which water flows downwards through the soil is always greater than then that being supplied by rainfall. In poorly drained soils the rate of infiltration at the soil surface is regularly exceeded by the rainfall rate due to:

- Low *hydraulic conductivity* in the subsoil (or a layer of the subsoil)
- High watertable due to low lying position and poor/poorly-maintained outfall
- Upward movement of water from seepage and springs

To achieve effective drainage the works will have to solve one or more of these problems and possibly a combination of all three. The objective of any form of land drainage is to lower the water-table providing suitable conditions for grass growth and utilization. A controlled water table promotes deeper rooting which improves sward productivity. It also improves load-bearing capacity of the soil and lessens the damage caused by grazing and machinery. When planning any drainage programme, the potential of the land to be drained needs to be first assessed to determine if the costs incurred will result in an economic return through additional yield and utilisation of the grass or other crops grown. Some thought is needed in deciding the most appropriate part of the farm to drain. From a management point of view it is better to drain that land which is nearer to the farmyard and work outwards, however it may be more beneficial to decide where to commence works once the drainage potential has been established by site investigation. This ensures a better return on the investment.

4.1 Drainage investigations

The land drainage problems encountered in Ireland are complex and varied and a full understanding of the issues involved is required before commencing drainage works. The first step is a detailed investigation into the causes of poor drainage

.

Knowledge of previous drainage schemes in the area, and their effectiveness will often provide an insight into the causes. A number of test pits (at least 2.5 m deep) should be excavated within the area to be drained. The test pits should be dug in areas that are representative of area as a whole. As the test pits are dug, the faces of the pits are observed, soil type should be established and the rate and depth of water seepage into the test pit (if any) recorded. Visible cracking, areas of looser soil and rooting depth should be noted as these can convey important information regarding the drainage status of the different layers. The depth and type of the drain to be installed will depend on the interpretation of the characteristics revealed by the test pits.

<u>Types of drainage system</u>

Two principle types of drainage system are distinguished:

- Groundwater drainage system: A network of piped drains establishing a deep drainage base in the soil
- Shallow drainage system: These are used to where soil is clayey (heavy) and infiltration of water is impeded at all depths

<u>Groundwater Drainage System</u>

In test pits where there is strong inflow of water or seepages from the faces of the pit walls, indicates that layers of high *hydraulic conductivity* are present. Under these circumstances the use of a piped drainage system is advised. The installation of a piped drain at the depth of inflow will facilitate the removal of groundwater assuming a suitable outfall is available. Conventional piped drains at depths of 0.8 to 1.5 m below ground level (BGL) have been successful where they encounter layers of high *hydraulic conductivity*. However, where layers with high *hydraulic conductivity* are deeper than this, deep drains are required. Deep piped drains are usually installed at a depth of 1.5-2.5 m and at spacings of 15–50 m, depending on the slope of the land and the *hydraulic conductivity* and thickness of the drainage layer. Piped drains should always be installed across the slope to intercept as much groundwater as possible, with open drains and main piped drains running in the direction of maximum slope.

Due to the risk of drain collapse, deep drains are normally excavated with a tracked digger with a special deep-drain trapezoidal bucket with a bottom width of about 200 mm. For small jobs a 300mm or similar sized bucket may be used but the side walls must be well battered (sloped) to avoid cave-ins. While these drains are more difficult to install, they are very cost effective as so few are required. Where groundwater seepage and springs are identified, deep drains, 2 to 3 m BGL can be used to intercept flow. Pipe drains are most effective in or on the aquifer (layer transmitting groundwater flow characterised by high water breakthrough). This issue is very site specific.

Clean aggregate should to be used to surround the land-drain pipe in conventional and deep drains. The gravel should be filled to a minimum depth of 300 mm from the bottom of the drain to cover the pipe. The stone should provide maximum connectivity to a layer of high *hydraulic conductivity*. The purpose of a drain pipe is to facilitate a path of least resistance for water flow. In long drain lengths (greater than 30m) a drain pipe is vital to allow a high a flow-rate as possible from the drain, stone backfill alone is unlikely to have sufficient flow capacity to cater for the water volume collected. Only short drain lengths (less than 30 m, or the upstream 30m of any drain) are capable of operating at full efficiency without a pipe.

Fig. 1a .Test pit excavation

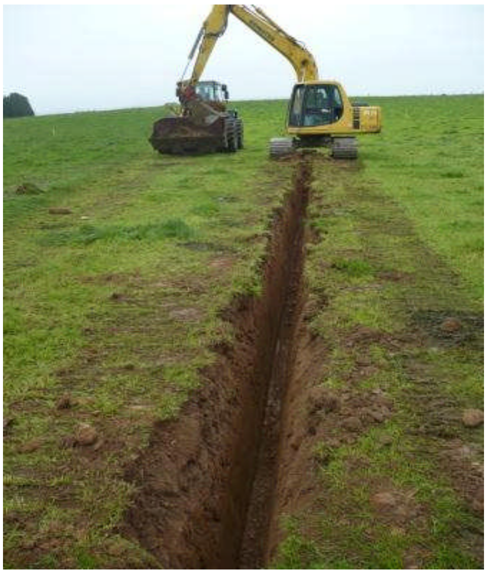

Fig 1b. Drainage trench excavation

Shallow Drainage Systems

Where a test pit shows little ingress of water at any depth a shallow drainage system is required. These soils that have no obvious permeable layer and very low hydraulic conductivity are more difficult to drain. Shallow drainage systems are those that aim to improve the capacity of the soil to transmit water, these include mole drainage and gravel mole drainage. The aim of these drainage techniques is to improve hydraulic conductivity by fracturing and cracking the soil and to form a network of closely spaced channels.

Mole drainage is suited to soils with a high clay content which form stable channels. Mole drains are formed with a mole plough comprised of a torpedo-like cylindrical foot attached to a narrow leg, followed by a slightly larger diameter cylindrical expander. The foot and trailing expander form the mole channel while the leg creates a narrow slot that extends from the soil surface down to the mole channel depth. The success of mole drainage depends on the formation of cracks in the soil that radiate from the tip of the mole plough at shallow depths as the soil is displaced forwards, sideways and upwards. Below a *critical depth*, dependent on soil mechanical strength and mole plough geometry, the soil flows forwards and sideways, bringing about compaction at the foot of the plough. Thus the action of the mole plough creates both a zone of increased hydraulic conductivity adjacent to the mole leg (shallower depths) and a channel for water conveyance and outflow at moling depth.

The effectiveness of mole drains depends on the extent of suitable cracking during installation. As such the ideal time for carrying out mole drainage is during dry summer conditions, this will cause maximum cracking in the upper soil layers as well as facilitating adequate traction preventing wheel-spin on the surface.

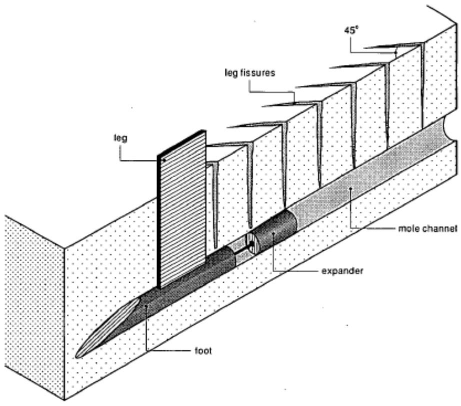

Fig. 2a .Mole plough showing cylindrical foot and expander, 2b. Cracking and channel formation

Gravel filled moles employ the same principles as ordinary mole drains but are required where an ordinary mole will not remain open for a sufficiently long period to render its application economical. This is the case in unstable soils having lower clay content. The mole channel is formed in a similar manner but the channel is then filled with gravel which supports the channel walls. The gravel mole plough carries a hopper which has a hydraulically operated shutter to control the flow of gravel; the gravel chute also has an adjustable door which regulates the height of gravel in the mole channel. During the operation the hopper is filled using a loading shovel or alternatively a belt conveyor from an adjacent gravel cart. Gravel moles require a very specific size range of gravel aggregate to ensure that they function properly. Washed aggregate within a 10-20 mm size range should be used.

Subsoiling is used effectively where an iron pan or cemented layer impedes drainage. The effect is to break the layer and crack the soil. A stable outlet channel will not be formed.

Fig. 3a. Gravel Mole plough showing hopper, 3b. Operation and filling of gravel mole plough

Collector drains, which are installed across the slope at 0.75 m BGL, are required for all mole drains. Depending on the topography and slope the collector drains will be at a spacing of 10–60 m. A larger spacing reduces costs but results in a higher chance of failure. The mole drains themselves are drawn at right angles to the collectors (up-slope) at spacings of 1.0-1.5 m and a depth of approximately 0.4-0.5 m. Stone backfill for collectors should be filled to within 250 mm of the surface to ensure interconnection with the mole channels.

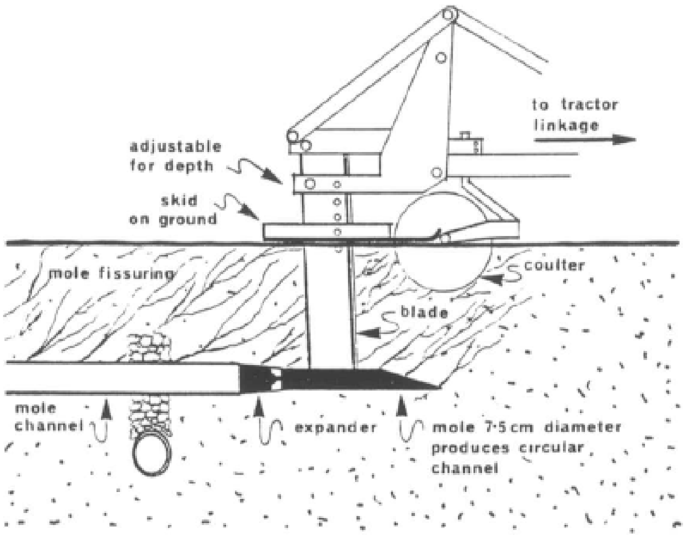

Fig. 4. Mole ploughing showing intersection with a piped collector drain

Outfalls/Maintenance

Every drainage scheme is only as good as its outfall. Cleaning and upgrading of open drains acting as outfalls from land drains is an important step in any drainage scheme. Before commencing land drainage the proposed outfall should be assessed and where necessary upgraded. Open drains, running in the direction of maximum slope, should be established to a great a depth as possible. This will maximise the potential for land drainage, with associated benefits. Spoil from such works, where suitable, can be spread over the adjoining land filling depressions and should not impede surface runoff to the watercourse. Unsuitable spoil should be buried and covered with topsoil or removed to waste ground.

When a drainage scheme has been completed, the layout should be drawn and noted on a farm map. This map can then be used as a guide when maintaining the works, as well as a record of the works. Land drain outlets should be regularly cleaned and maintained especially if open drains are cleaned/upgraded as this may result in blockages at the drain outlet. The use of a concrete or un-perforated plastic pipe over the end of the drain pipe, minimum 1 m in length, will protect the outlet from damage and will make locating and maintaining it easier.

4.2 Cost benefit analysis

The cost of drainage works will vary depending on such factors as soil type, site access, extent of open drains, availability/cost of backfill stone, and experience with drainage works among other factors. As such, costs are quite variable and will be specific to a particular job. The table below provides guidelines only. Cost for the provision of open drains is not included.

The Table 7 covers as far as possible the general arrangements available. Where a shallow drainage system is considered the price will depend largely on the collector drains required. If an existing drainage system of closely spaced piped drains is already in place at the appropriate depth BGL is already in place it may be possible to pull mole drains through this existing network or from an existing open drains. In this case the cost of mole drainage can be very cost effective. Where a collector system needs to be installed the total cost will be higher.

Table 7: Approximate costs of different land drainage systems

Drainage System	Drain Spacing (m)	Depth (m)	Cost/m (€)	Cost/ha (€)
Groundwater Drainage systems				
Conventional	8	0.8 - 1.5	5-7	6,200-8,600
Deep Drainage	15 - 50	1.5 - 2.5	9-11	3,700-6,200
Shallow Drainage systems				
Mole	1 - 1.5	0.45 - 0.6	-	125
Gravel Mole	1 - 1.5	0.35 - 0.5	-	1,480
Collector Drains	20	0.75	5-7	2,500-3,500
Collector Drains	40	0.75	5-7	1,200-1,700
Collector Drains	60	0.75	5-7	800-1,150

It is of the utmost importance that the selection of a drainage system for a particular site is not decided on the basis of cost. Alternatively an effective drainage system should be designed and costed and then a decision made as to whether or not to proceed.

Table 8: Assumption use in the cost benefit analysis	
Farm land area (ha)	40
Concentrate Costs (€/t)	250
Replacement heifer costs (€)	1,400
Capital Costs (€/cow)	1,500
Male calf value (€)	100
Cull cow value (€)	515
Herd replacement rate (%)	20

Table 8 shows the key assumptions used in the farm model to investigate the costs benefit of different drainage systems. The base farm consisted of 40 ha, with 65 dairy cows, stocked at 1.6 cows/ha and producing 5,437 kg/cow.

Four drainage systems were evaluated based on draining 30% of the base farm (12 hectares). The systems evaluated were mole draining with collector drains 20 meters apart, gravel mole with collector drains at 20 meters apart, deep drains (1.5 to 2.5 meters depth) at 30 meters apart and conventional drains (0.8 to 1.5 meters depth) at 10 meters apart. The cost benefit of a 10%, 20% and 30% increase in grass production were evaluated, at a milk price of 22, 28 and 34 cents per litre respectively.

Table 9.: Cost benefit analysis of a shallow drainage system incorporating naked moles plus collector drains costing €3,090/ha				
Herbage Production Increase	Base Farm	10%	20%	30%
Milk Production (kg)	353,391	403,241	432,348	460,940
Milk Sales (kg)	345,825	394,608	423,092	451,072
Cow numbers	65	74.2	79.5	84.8
SR (cows/ha)	1.6	1.9	2.0	2.1
Protein sales (kg)	12,466	14,225	15,252	16,260
Fat sales (kg)	14,876	16,975	18,200	19,403
Grass Growth (t DM/ha)	8,943	9,838	10,725	11,626
Grass Utilisation (t DM/ha)	6,708	7,870	8,580	9,301
Grass utilisation %	75	80	80	80
Proportion of the farm drained	30	30	30	30
Depreciation costs (€)	16,541	20,099	20,734	21,358
Interest rates costs (€)	10,076	13,326	13,639	13,945
Total costs (€)	110,385	126,309	132,579	138,739
Milk Returns @22cpl (€)	87,640	100,008	107,221	114,312
Profit @ 22cpl (€)	-2,376	-3,051	-406	2,191

Milk Returns @28cpl (€)	111,452	127,174	136,353	145,371
Profit @ 28cpl (€)	21,587	24,292	28,911	32,447
Milk Returns @34cpl €)	135,264	154,344	165,485	176,429
Profit @ 34cpl (€)	45,549	51,636	58,288	64,703

Table 9 shows the cost benefit analysis of using a shallow drainage system using naked moles with collector drains 20 meters apart. Apart from a scenario where milk price was at 22 cent /litre and grass production increase was less than 20% increase there was an economic advantage to using a shallow drainage system using mole with collector drains at 20 meters apart.

Table 10:	**Cost benefit analysis of a shallow drainage system incorporating gravel moles plus collector drains costing €4,500/ha**			
Herbage Production Increase	Base Farm	10%	20%	30%
Milk Production (kg)	353,391	403,241	432,348	460,940
Milk Sales (kg)	345,825	394,608	423,092	451,072
Cow numbers	65	74.2	79.5	84.8
SR (cows/ha)	1.6	1.9	2.0	2.1
Protein sales (kg)	12,466	14,225	15,252	16,260
Fat sales (kg)	14,876	16,975	18,200	19,403
Grass Growth (t DM/ha)	8,943	9,838	10,725	11,626
Grass Utilisation (t DM/ha)	6,708	7,870	8,580	9,301
Grass utilisation %	75	80	80	80
Proportion of the farm drained	30	30	30	30
Depreciation costs (€)	16,541	21,186	21,821	22,441
Interest rates costs (€)	10,076	14,521	14,833	15,141
Total costs (€)	110,385	128,591	134,861	141,029
Milk Returns @22cpl (€)	87,640	100,008	107,221	114,312
Profit @ 22cpl (€)	-2,376	-5,341	-2,697	-99
Milk Returns @28cpl (€)	111,452	127,174	136,353	145,371
Profit @ 28cpl (€)	21,587	22,002	26,620	31,157
Milk Returns @34cpl €)	135,264	154,344	165,485	176,429
Profit @ 34cpl (€)	45,549	49,345	55,937	62,413

Table 10 shows the cost benefit analysis of using a shallow drainage system using gravel moles with collector drains 20 meters apart. In this scenario there was an economic advantage to the drainage system when milk price was at 28 and 34 cent per litre while at 22 cent per litre there was no advantage.

Table 11 shows the cost benefit analysis of using a deep drainage system (1.5 to 2.5 meters depth) at 30 meters apart. Similar to the shallow gravel system there was an economic advantage where milk price was 28 and 34 cent/litre, while at 22 cent per litre there was no advantage.

Table 11: Cost benefit analysis of a deep drainage system costing €4,950/ha

Herbage Production Increase	Base Farm	10%	20%	30%
Milk Production (kg)	353,391	403,241	432,348	460,940
Milk Sales (kg)	345,825	394,608	423,092	451,072
Cow numbers	65	74.2	79.5	84.8
SR (cows/ha)	1.6	1.9	2.0	2.1
Protein sales (kg)	12,466	14,225	15,252	16,260
Fat sales (kg)	14,876	16,975	18,200	19,403
Grass Growth (t DM/ha)	8,943	9,838	10,725	11,626
Grass Utilisation (t DM/ha)	6,708	7,870	8,580	9,301
Grass utilisation %	75	80	80	80
Proportion of the farm drained	30	30	30	30
Depreciation costs (€)	16,541	21,582	22,217	22,840
Interest rates costs (€)	10,076	14,955	15,268	15,575
Total costs (€)	110,385	129,420	135,691	141,851
Milk Returns @22cpl (€)	87,640	100,008	107,221	114,312
Profit @ 22cpl (€)	-2,376	-6,174	-3,529	-932
Milk Returns @28cpl (€)	111,452	127,174	136,353	145,371
Profit @ 28cpl (€)	21,587	21,169	25,788	30,324
Milk Returns @34cpl €)	135,264	154,344	165,485	176,429
Profit @ 34cpl (€)	45,549	48,512	55,105	61,580

Table 12 shows the cost benefit analysis of using a conventional drainage system (0.8 to 1.5 meters depth) at 10 meters apart. With this drainage system there was no economic advantage at a milk price of 22 cent per litre, while at 28 cent per litre a 20 or 30% increase in grass DM production was required to make it financial beneficial.

The 10, 20 and 30% increase in DM production equate to approximately 4, 6.25 and 8.5 tonnes of DM production on the 30% of the farm drained in the cost benefit analysis carried out. Additionally, it is assumed that the drainage systems will increase grass utilisation by 5%. It is very important that these benefits to land drainage are achievable before large investments are carried out at farm level.

Table 12: Cost benefit analysis of a conventional drainage system costing €7,400/ha				
Herbage Production Increase	Base Farm	10%	20%	30%
Milk Production (kg)	353,391	403,241	432,348	460,940
Milk Sales (kg)	345,825	394,608	423,092	451,072
Cow numbers	65	74.2	79.5	84.8
SR (cows/ha)	1.6	1.9	2.0	2.1
Protein sales (kg)	12,466	14,225	15,252	16,260
Fat sales (kg)	14,876	16,975	18,200	19,403
Grass Growth (t DM/ha)	8,943	9,838	10,725	11,626
Grass Utilisation (t DM/ha)	6,708	7,870	8,580	9,301
Grass utilisation %	75	80	80	80
Proportion of the farm drained	30	30	30	30
Depreciation costs (€)	16,541	23,559	24,193	24,819
Interest Rates COSTS (€)	10,076	17,127	17,440	17,747
Total costs (€)	110,385	133,569	139,840	146,000
Milk Returns @22cpl (€)	87,640	100,008	107,221	114,312
Profit @ 22cpl (€)	-2,376	-10,339	-7,694	-5,096
Milk Returns @28cpl (€)	111,452	127,174	136,353	145,371
Profit @ 28cpl (€)	21,587	17,005	21,623	26,159
Milk Returns @34cpl €)	135,264	154,344	165,485	176,429
Profit @ 34cpl (€)	45,549	44,348	50,940	57,415

5. Conclusions

With the abolition of milk quota in 2015 there are great opportunities for expansion in milk output. The programme farms have been increasing herd size and milk output over the years by improving grass output on the better sections of their farms. Further expansion necessitates that they now focus on the more marginal land areas, which will in most cases require some drainage. This five year project, which started last year, will apply and test the most appropriate technologies across a range of challenging soil types to ensure efficient and profitable expansion.

A web page has been constructed to disseminate information from the programme to interested farmers and advisory personnel and is available on the Teagasc website http://www.teagasc.ie/heavysoils