Design, Establishment and Development

Version Number: 1.3

Document Description
Details of the creation and ongoing development of the North Wyke Farm Platform.

Associated Documents	**Description**
Technical Case Study No. 1	Determination of areas using GPS and GIS
FP_UG.Doc.002_15MinData	User Guide to 15 Minute Data
FP_UG.Doc.004_FieldEvents&LivestockData	User Guide to field events and livestock data
Draft report v5 (31 Oct 08)	Hydrological Design
Revised flow estimates (18 Aug 09)	Flow estimates calculated for a range of flood magnitudes (flood return periods) and for a clay soil type.

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Change Record

Version Number	Date	Changes Made
1.1	22/07/2016	Figure 1 replaced - incorrect spelling of phosphorus.
1.2	06/09/2016	Conductivity changed to specific conductivity throughout
1.3	17/01/2017	Appendix 1 Sensor and Data collection section changed to include information on YSI 6600V2 multi-parameter sonde upgrade to YSI Exo and new logger installation.

Preface

The North Wyke Farm Platform (NWFP) represents a large investment by BBSRC in the future, to not only study but also improve grassland livestock systems in a national and global research asset linked to real-world farming. It is a world-class facility and a key member of the Global Farm Platform network http://www.globalfarmplatform.org/ which attracts researchers from different communities and disciplines seeking to develop sustainable ruminant production systems. It provides access to a range of in situ state-of-the-art instrumentation in hydrologically isolated (sub-) catchments to better address key issues in sustainable agriculture related to:

- Replacement of N fertiliser with N-fixation by legumes - achieving a reduction in energy and greenhouse gas emissions for both environmental and economic reasons.
- Using plants to manage soils and hydrology in green-engineering solutions to flooding.
- Efficient phosphorus cycling in grassland systems.
- Resilience of soil biota and their functions in land-use change.
- Impact of grassland management on carbon cycling and storage.
- Water resource use efficiency.
- Systems modelling to design optimal grassland production systems.

The NWFP provides three farming systems in farmlets, each consisting of five component catchments comprising approx. 21 ha in total per farmlet. Each farmlet is managed using alternative approaches to livestock production from grassland. Measurements on water, air and soil are also recorded. Much of this data has a fine-scale (15 minute) temporal resolution, such as water flow and water chemistry data measured at a flume for each of the 15 catchments, which can comprise either single or multiple fields. As a National Capability, the data collected are made publicly available.

The main farming systems or 'treatments' on the platform are:

1) Permanent pasture: improvement through use of inorganic fertilisers (Green farmlet).
2) Increased use of legumes: replacing nitrogen fertilisers with biological fixation using sown legume and grass mixtures (Blue farmlet).
3) Planned reseeding: regular renewal, providing opportunities for introducing innovative varieties with desirable traits. Currently, high sugar and deep rooting grasses are studied (Red farmlet).

See more at: http://www.rothamsted.ac.uk/farmplatform

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1 Document Description

This document gives details of the phases involved in the design, creation and ongoing development of the North Wyke Farm Platform (NWFP). A timeline of key events is given in Appendix 1.

2 Introduction

The NWFP is located on a ridge at 120 – 180 m above sea level, where the land slopes down on the west to the River Taw and on the east to one of its tributaries, the Cocktree stream. Over a 30-year period from 1982, the mean annual precipitation at the North Wyke site was 1044 mm; with the first, second and third quartiles of this annual distribution given at 924 mm, 1031 mm and 1158 mm, respectively. A significant feature of the site is the presence of clay-rich subsoils beneath the sub-surface horizons. Below the topsoil layer, the subsoil is highly impermeable to water and is seasonally waterlogged with most excess water leaving by surface and sub-surface lateral flow across the clay layer. This pattern in the movement of water allows for interception by a bounded drainage system and was a key factor in making this farm-scale experiment viable.

The NWFP consists of three individual 'farmlets' each of which (since modifications were effected on 13 August 2013) is approximately 21 ha and has been designed to test the productivity and environmental sustainability of contrasting temperate grassland beef and sheep systems at appropriate farm and land management scales (Figure 1).
The main farming systems or treatments on the platform are:

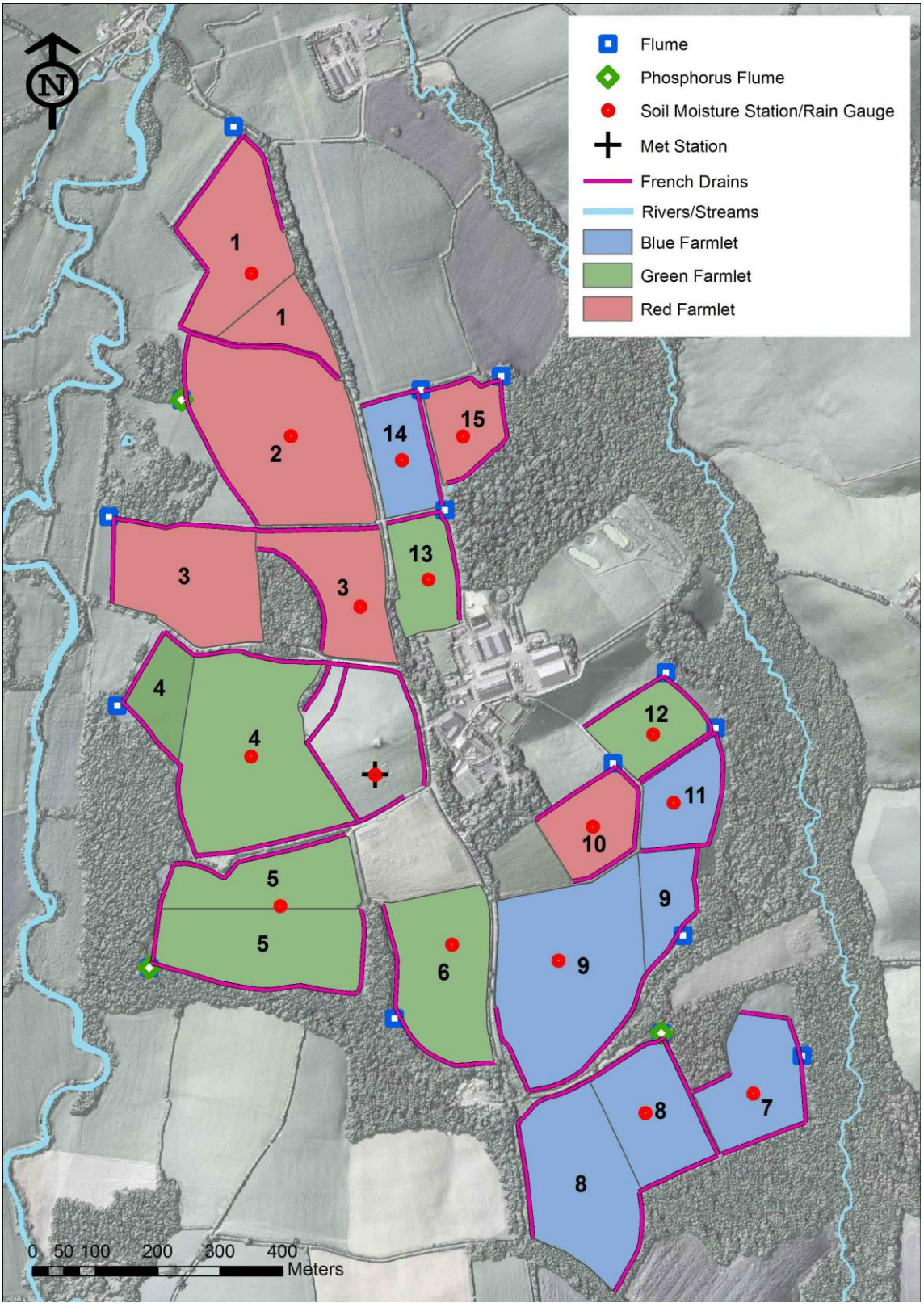
1. Permanent pasture: improvement through use of inorganic fertilisers (Green farmlet).
2. Increased use of legumes: replacing nitrogen fertilisers with biological fixation using sown legume and grass mixtures (Blue farmlet).
3. Planned reseeding: regular renewal, providing opportunities for introducing innovative varieties with desirable traits. Currently, high sugar and deep rooting grasses are studied (Red Farmlet).

Each of the three farmlets contains five (sub-) catchments (15 in total), with each catchment hydrologically isolated through a combination of topography and a network of 9.2 km of drains constructed around the perimeters of each catchment. The drainage network is made up of 800 mm deep trenches containing perforated drainage pipe and backfilled to the surface with 20-50 mm clean, carbonate-free granite chips. The trench bed and outer face are lined with

plastic damp proof plastic membrane. This type of construction is commonly referred to as a French drain [French, 1859]. Each of the sub-catchments was allocated to one of the three farmlets according to some or all of the following conditions:

1. Expert knowledge of the physical properties of the North Wyke site.
2. The need for a degree of spatial connectivity between the five sub-catchments of each farmlet.
3. Historical farm practice.
4. Farm/research operational requirements.

Figure 1. Map of NWFP showing treatments as of 2015: Green farmlet = permanent pasture, Blue farmlet = legumes; Red farmlet = planned reseeding.



3 Site Details, Design and Establishment

3.1 Location

The NWFP is located on the Rothamsted Research, North Wyke Farm (Figure 2) in the South West England (50º46'10" N, 3º54'05" W) with an average annual rainfall of 1056mm and is located on a ridge at 120 – 180 m above sea level, where the land slopes down on the west to the River Taw and on the east to one of its tributaries, the Cocktree stream. LiDAR data are available [Ferraccioli et al., 2014] providing both a digital surface model (DSM) and a digital terrain model (DTM) of the NWFP (see representations given in Figure 3).

Figure 2. Location of the NWFP

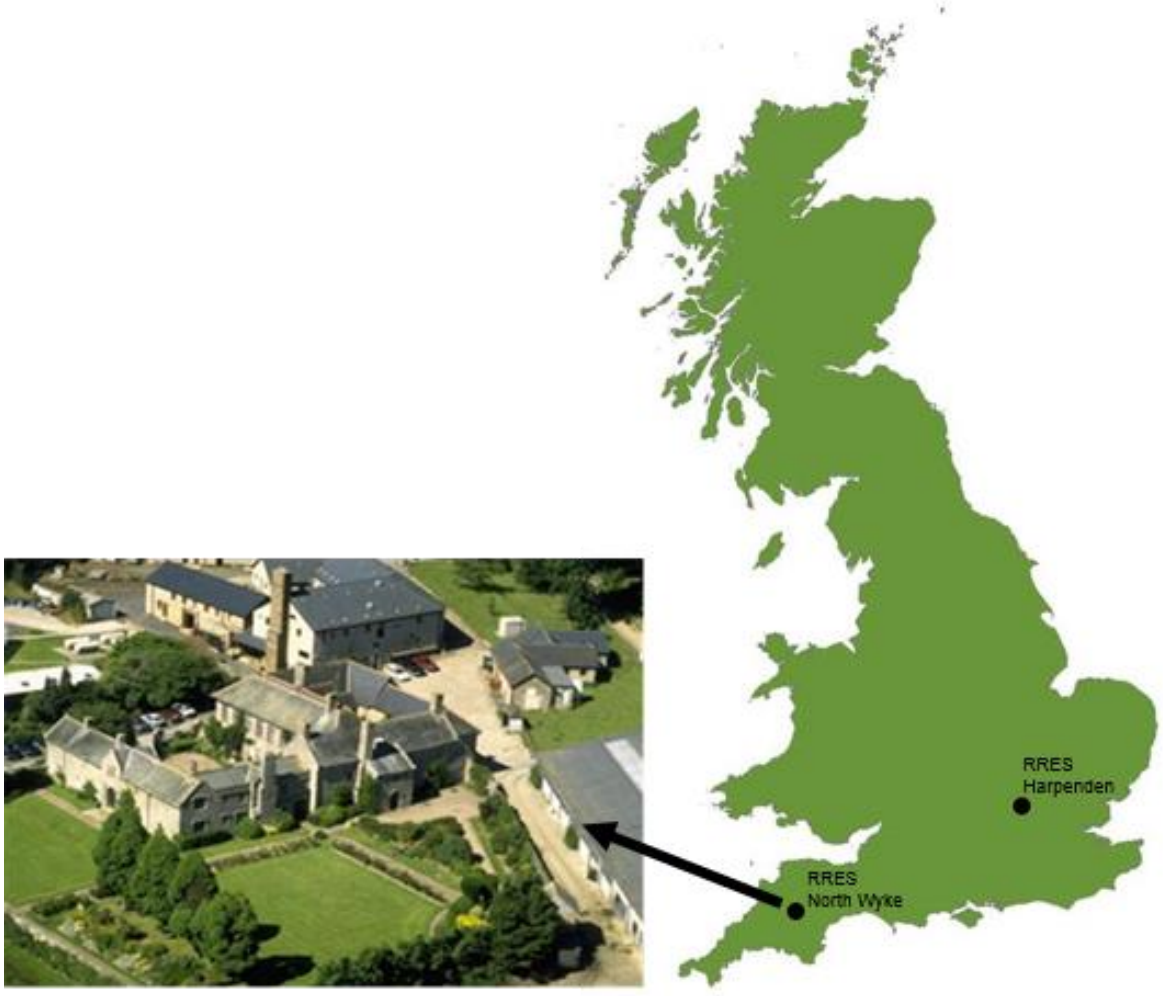
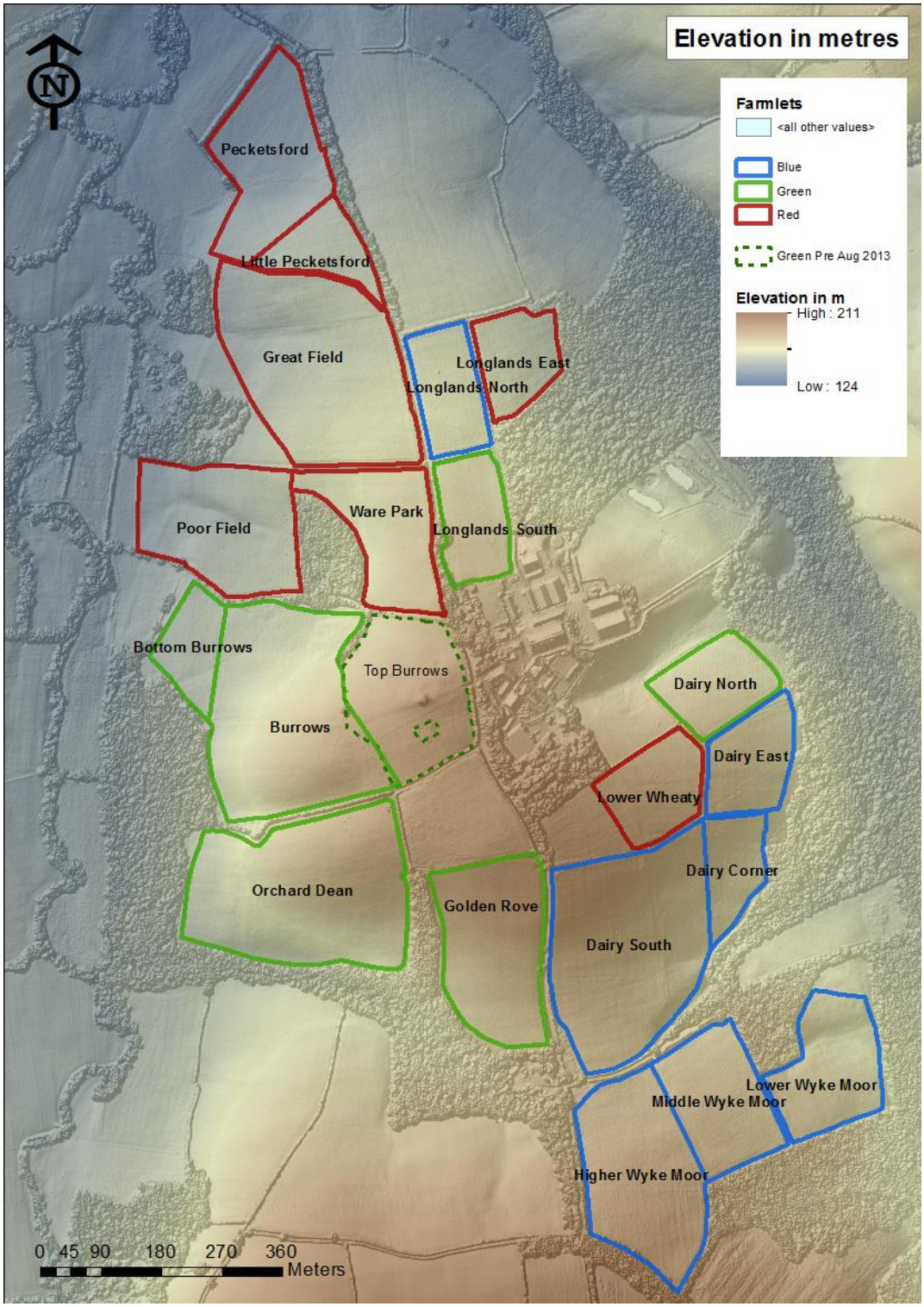


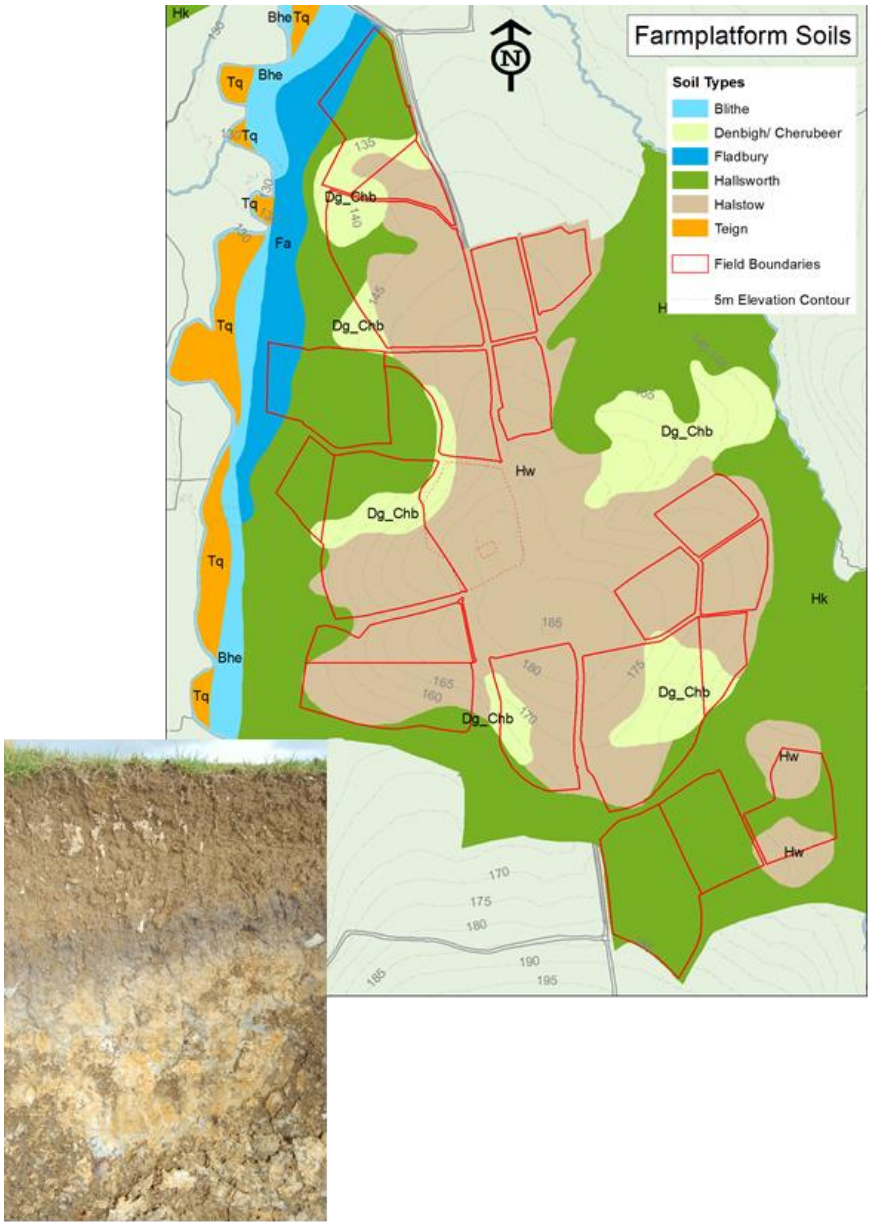
Figure 3. Topographic representations of the NWFP.



3.2 Soil

A key feature of the site is the presence of clay-rich sub-soils beneath the sub surface horizons. The soil is predominantly of two similar series, Hallsworth (Dystric Gleysol) and Halstow (Gleyic Cambisol), that comprise of a slightly stony clay loam topsoil (approximately 36% clay) overlying a mottled stoney clay (approximately 60% clay), derived from carboniferous culm measures [Harrod T.R and Hogan D.V, 2008]. The sub-soils data is depicted in Figure 4, together with the 15 NWFP catchments and 21 field boundaries.

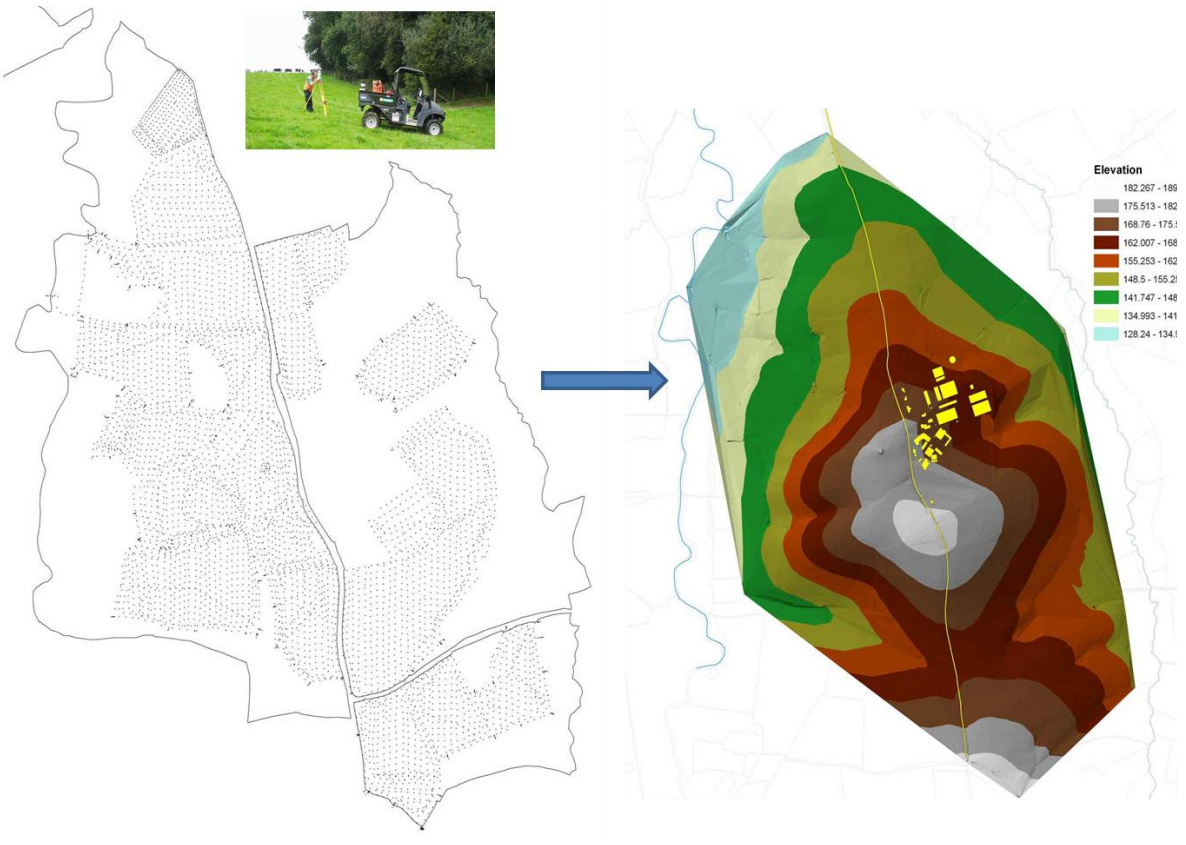
Figure 4. Map of the soils of the NWFP and a typical soil profile



3.3 Site survey and assessment

Rothamsted Research, North Wyke commissioned JBA [JBA Consulting, Bradford] to carry out an assessment of the surface water and potential groundwater interactions on the land where the experimental areas had been proposed by North Wyke staff, based on their local knowledge, together with reference to existing digital terrain model (DTM) datasets described previously. In order to accurately define the topographic boundaries of the proposed area, JBA commissioned Storm Geomatics [Storm Geomatics Ltd, Gloucestershire] to undertake a 15m gridded GPS ground level survey of all the fields in question, including some basic surveying of the existing open ditch network. Storm Geomatics undertook the survey in September 2008 followed by a detailed site assessment shortly after by JBA (Figure 5).

Figure 5. Measurement of the topography for the proposed siting of the NWFP



In particular, the JBA assessment included the following tasks:

1. Identification of how the catchments could be hydrologically isolated in terms of the surface water.
2. Consideration of the possibility of any groundwater interactions within the catchments.
3. Recommendations for the locations and outline specification for a flow monitoring station at the outlet to each block.

3.4 Planning Permission

Prior to obtaining planning permission for the construction of the Farm Platform, various conditions had to be met including:

- obtain Flood Defence Consent from the UK Environment Agency.

- conduct a Badger Survey to describe and evaluate the status of badgers in the area, identify potential impacts that the proposed works may have on badgers and their setts and provide recommendations to mitigate these impacts.

- conduct a Tree Species and Condition Survey and Constraints Plan in relation to Root Protection Areas (RPA). Identify location, species, dimensions, age class, condition and remaining contribution in years and produce a Protection Plan and Arboricultural Method Statement which documents how the trees were to be protected from inadvertent damage.

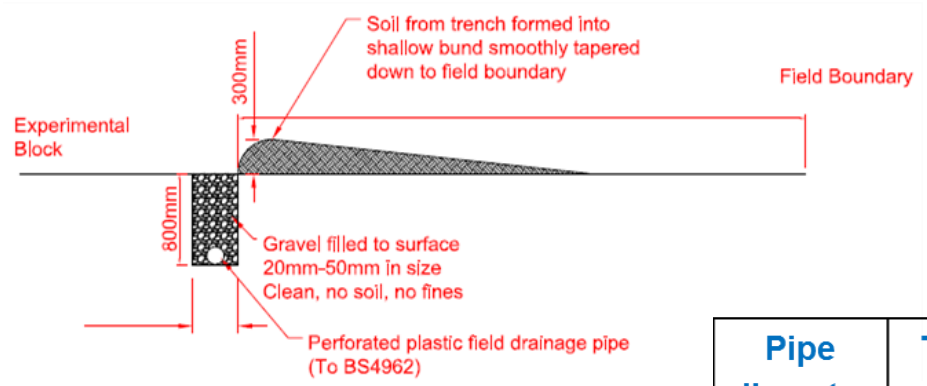
- conduct an Extended Phase 1 Habitat and Protected Species survey to identify records relating to bat and other notable species (Joint Nature Conservation Committee, 1993) as amended by Institute of Environmental Assessment (1995) with additional emphasis on searching for protected species, their field signs or identifying habitats which may support protected species.

- conduct an Environmental Impact Assessment including an Archaeological Survey and Groundworks Mitigation Plan.

3.5 Construction of French Drains

Establishment of the NWFP began in 2010. The hydrological monitoring design was based on a predicted 1 in 50-year flood event (using data revised in August 2009; Appendix 1), with open channel flow nozzles (H-flumes http://tracomfrp.com) at the catchment outlets, each sized according to the catchment characteristics. In order to collect surface and surface lateral flow, French drains totalling 9.2 km in length were constructed by digging trenches to a depth of 800m, lining them with damp proof membrane, and placing a perforated plastic drainage pipe centrally in the trench bed. The width of the drains was dependent on the drainage pipe diameter + 100mm each side (Figure 6) and to facilitate this, eight different digger bucket sizes were fabricated.

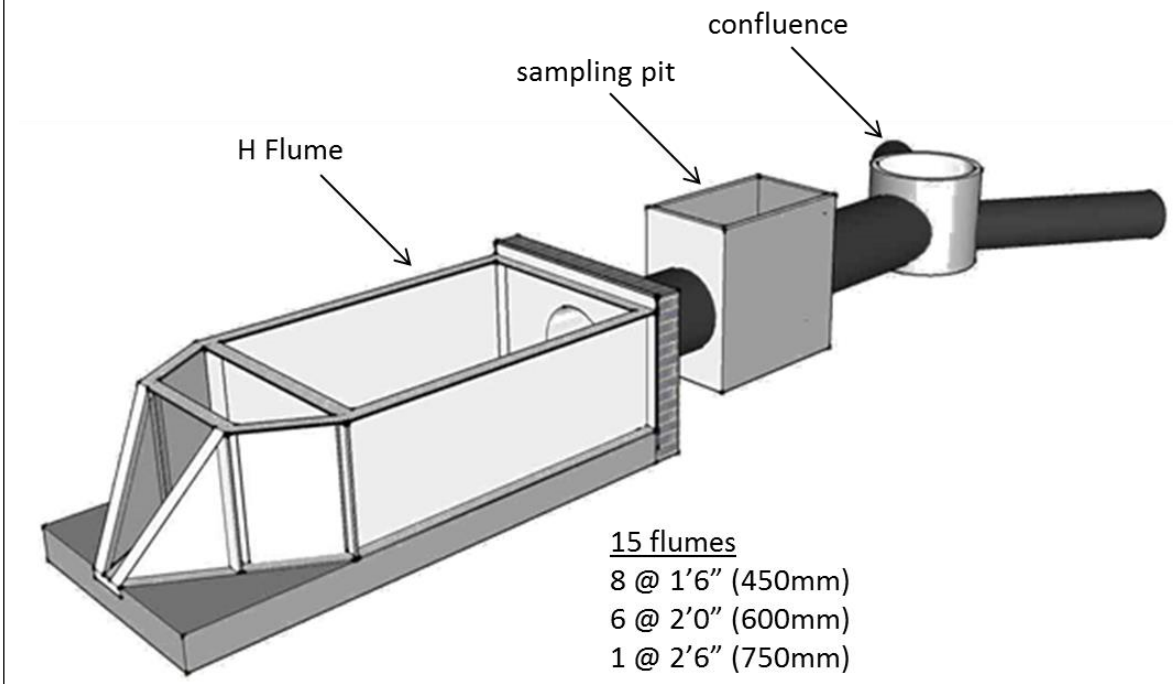
Figure 6. Design of French drains, pipe diameters, and an example of a completed drain



Pipe diameter (mm)	Trench width (mm)
100	300
160	360
200	400
225	425
300	500
375	575
400	600
450	650

The trenches were backfilled using 5056 tonnes in total of 20 – 50 mm clean granite stone. All the flumes receive water supplied by 2 branches of the drains and where these join in a confluence pit, puddled clay stanks were placed around the pipe to ensure the drainage water is always captured. The water is then channelled via concrete piping and a sampling pit into the flume (Figure 7). Where required, the experimental areas have been protected on the upslope boundaries by open ditches and sealed pipes to prevent ingress of external groundwater and surface runoff from adjacent land. Each flume is supplied with mains electric power and a fibre optic cable based data telemetry system which totals over 5 km in length. The completed drainage network is shown in Figures 8 and 9.

Figure 7. Design of hydrological monitoring system, and number and size of H flumes used.



Once completed, livestock fencing was put in place so as to avoid damage and contamination of the surface of the drains by grazing animals. The exclusion of these areas has resulted in slight differences in the operational zones contributing to agronomic and hydrology data (Table 1). The exact areas have been calculated using GPS and a GIS (see Technical Case Study No. 1).

Figure 8. Network of French drains – section lengths (m)

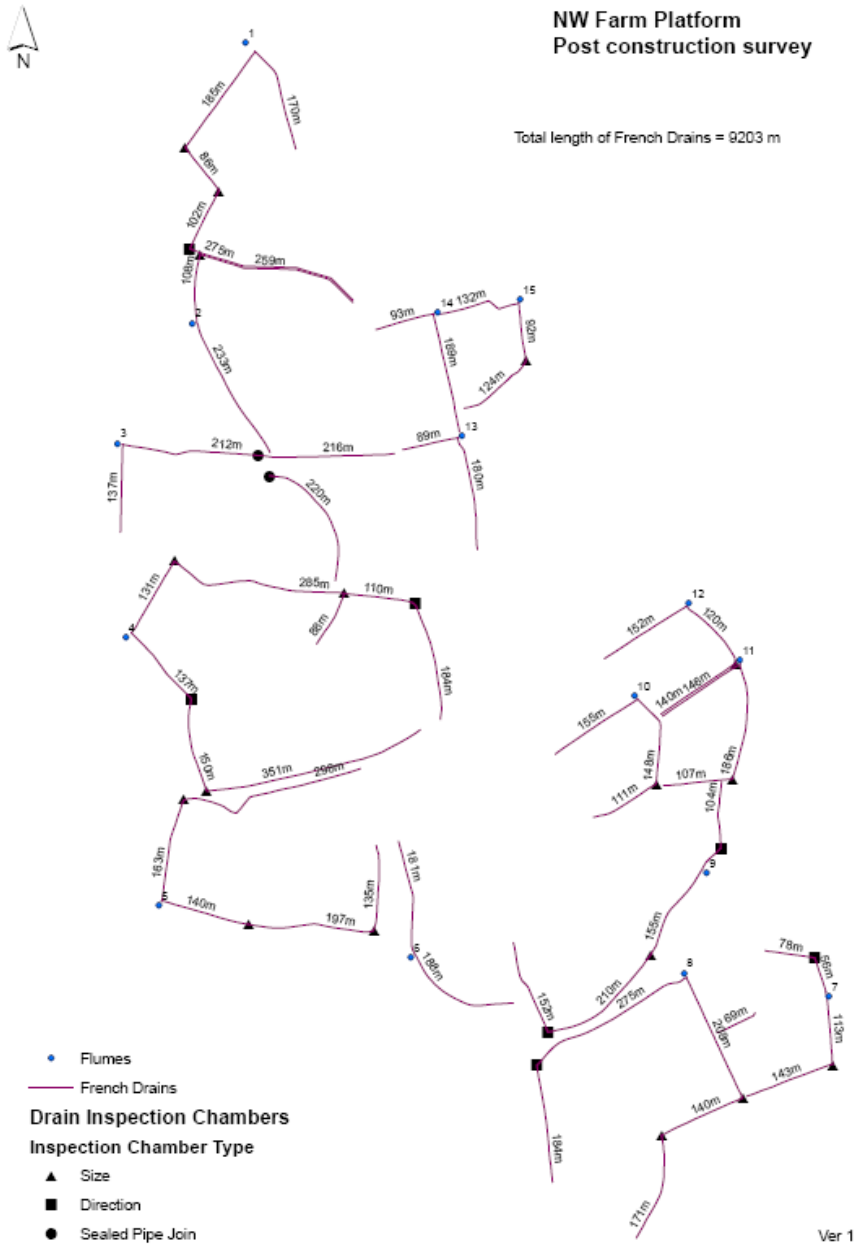
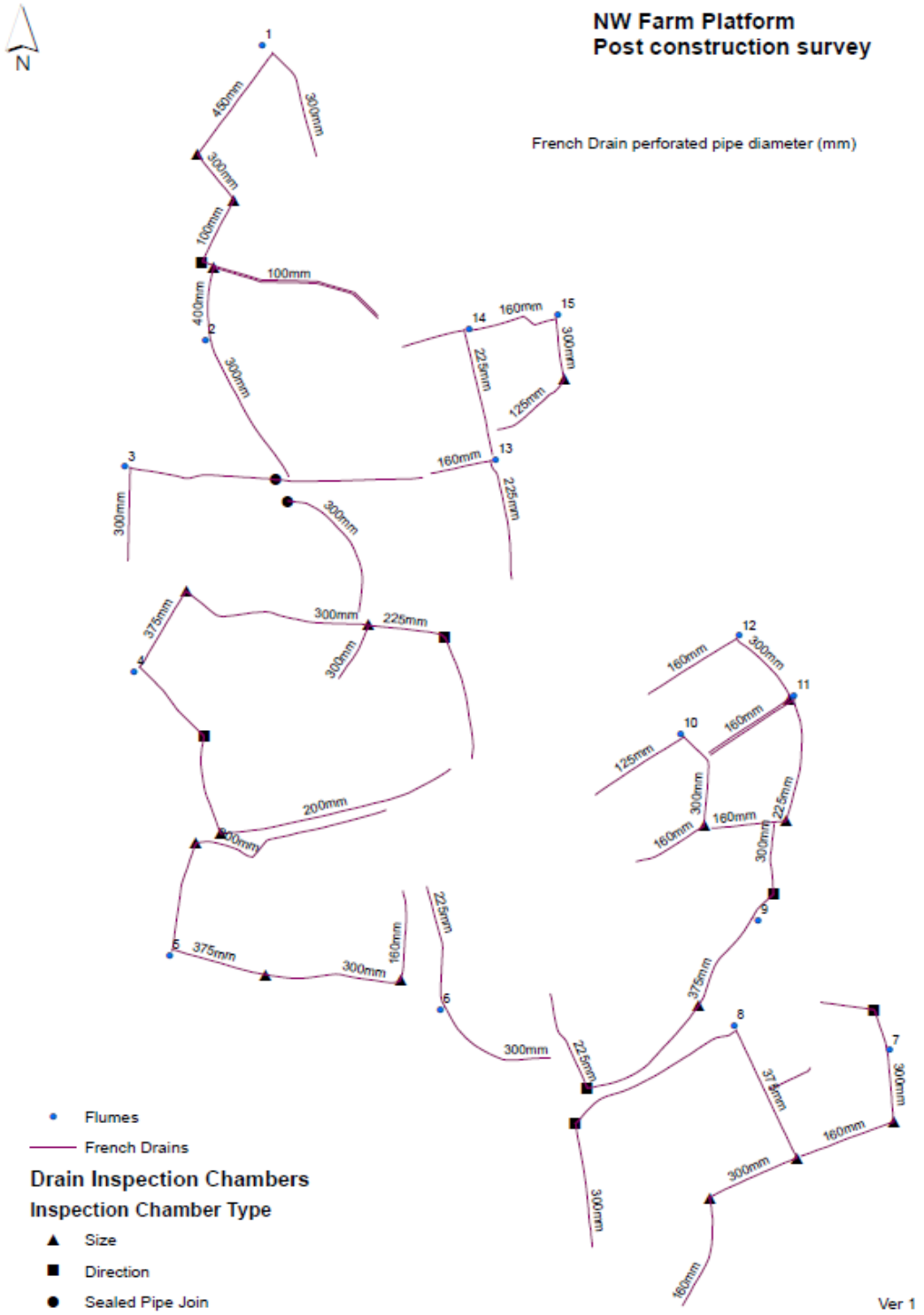


Figure 9. Network of French drains – pipe diameter (mm)†



†Bespoke inspection chambers were installed where pipe size or direction changed.

Table 1. Name of field and area contributing to each catchment flume on the three NWFP farmlets as of 2015.

Red Farmlet (Planned Reseeding)	Field Names	Fenced area (ha)	Total Fenced area (ha)	Total Hydrological area (ha)
Catchment/Flume 1	Pecketsford	3.50	4.81	5.00
	Little Pecketsford	1.31		
Catchment/Flume 2	Great Field	6.65	6.65	6.79
Catchment/Flume 3	Poor Field	3.92	6.62	4.03
	Ware Park	2.71		2.81
Catchment/Flume 10	Lower Wheaty	1.82	1.82	1.94
Catchment/Flume 15	Longlands East	1.54	1.54	1.62
	Total		**21.4**	**22.2**
Green Farmlet (Permanent Pasture)	**Field Names**	**Fenced area (ha)**	**Total Fenced area (ha)**	**Total Hydrological area (ha)**
Catchment/Flume 4 Pre-Aug 2013†	Burrows	6.39	11.12	11.55
	Bottom Burrows	1.26		
	Top Burrows	3.47		
Catchment/Flume 4 Post-Aug 2013†	Burrows	6.49	7.75	8.08
	Bottom Burrows	1.26		
Catchment/Flume 5	Orchard Dean North	2.55	6.47	6.73
	Orchard Dean South	3.92		
Catchment/Flume 6	Golden Rove	3.86	3.86	3.95
Catchment/Flume 12	Dairy North	1.78	1.78	1.87
Catchment/Flume 13	Longlands South	1.75	1.75	1.81
	Total pre-Aug 2013		**25.0**	**25.9**
	Total post-Aug 2013		**21.6**	**22.4**
Blue Farmlet (Legumes)	**Field Names**	**Fenced area (ha)**	**Total Fenced area (ha)**	**Total Hydrological area (ha)**
Catchment/Flume 7	Lower Wyke Moor	2.60	2.60	2.71
Catchment/Flume 8	Middle Wyke Moor	4.32	7.02	7.33
	Higher Wyke Moor	2.70		
Catchment/Flume 9	Dairy South	6.45	7.75	7.91
	Dairy Corner	1.30		
Catchment/Flume 11	Dairy East	1.76	1.76	1.85
Catchment/Flume 14	Longlands North	1.72	1.72	1.78
	Total		**20.8**	**21.6**

Total NWFP Area pre-Aug 2013†		**67.2**	**69.7**
Total NWFP Area post-Aug 2013†		**63.8**	**66.2**

†Initially Catchment/Flume 4 consisted of 3 fields, Bottom Burrows, Burrows and Top Burrows, which made up a total area of around 11 ha. As the Green farmlet (25 ha) was larger than the Red farmlet (21.4 ha) and the Blue farmlet (20.8 ha) it was decided to remove Top Burrows, which had an area of 3.47 ha, from the Farm Platform, in order for all farmlets to be of a similar size. Additional French Drains were constructed to intercept and divert water draining from Top Burrows away from Flume 4 and these were in place from 13 August 2013 onwards. The area of Burrows increased slightly after this date.

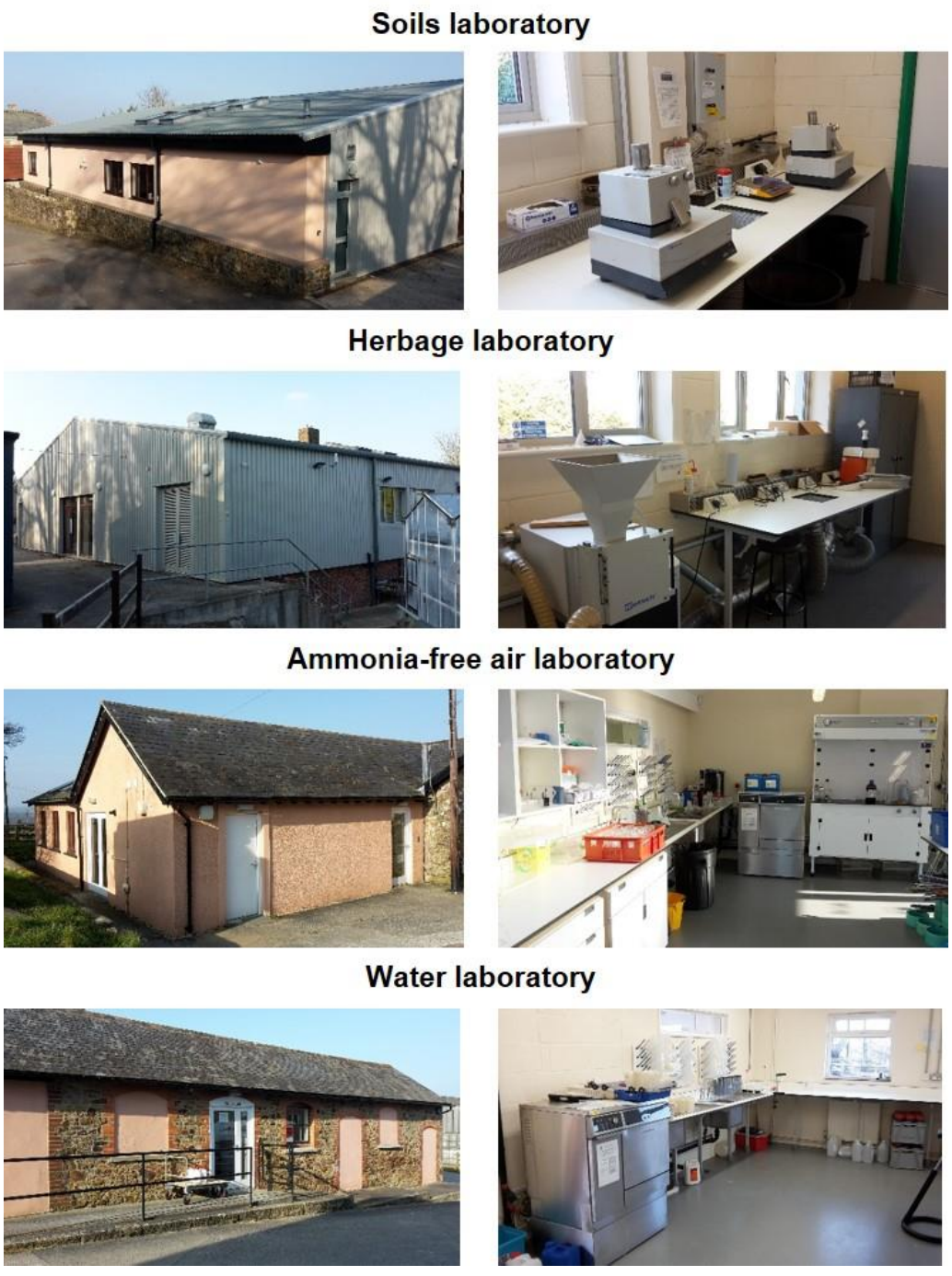
Up until 2015, water flow was measured using bubble flow meters, but these have since been replaced with pressure transducers. Other water measurements include nitrate, ammonium, dissolved oxygen, total phosphorus, ortho-phosphate, chloride, dissolved organic carbon, temperature, pH, specific conductivity, and turbidity are measured at 15 minute intervals at each flume. Under prescribed flow conditions, water is drawn up automatically from the sampling pit every 15 min by a bi-directional peristaltic pump to a purpose designed flow cell fitted with various sensors. The pump and flow cell are housed in a cabin that is sited at each flume (Figure 10). In addition, rainfall and soil moisture are measured at a central point on each catchment. A full description of the instrumentation, and collection and management of the 15 min data is given in the user guide entitled FP_UG.Doc.002_15MinData.

Figure 10. One of fifteen flume laboratories which are sited in each catchment.

3.6 Laboratory facilities

In 2010, as part of the Farm Platform development, separate laboratories (Figure 11) were created to handle Soil, Herbage, Air and Water to ensure the Quality Control over sample separation and facilitate efficient workflow.

Figure 11. Dedicated soils, herbage, air and water laboratories at North Wyke.



3.7 Livestock Buildings and Facilities

Three new cattle buildings (Figure 12) were built in the winter 2013/2014 which provided dedicated housing, silage clamps and farmyard manure (FYM) middens for each of the farmlets.

Figure 12. Dedicated cattle housing, silage clamps and FYM middens at North Wyke, Rowden site.

The grass harvested from June 2014 onwards was either stored in these clamps or in big bales which were linked to the farmlet. The FYM produced during the winter 2014/2015 by the cattle in the Red, Green or Blue buildings was returned to each respective farmlet in 2015 (Figure 13).

Figure 13. Spreading FYM on the farmlets.

4 Changes in Development & Farmlet Assignment

4.1 Change in size of Burrows Catchment (Flume 4)

For data relating to the period 21 March 2011 until 12 August 2013 the Burrows Catchment (Flume 4) consisted of 3 fields, Bottom Burrows, Burrows and Top Burrows, which made up a total area of around 11 ha. As the Green farmlet (25 ha) was larger than both the Red farmlet (21.4 ha) and the Blue farmlet (20.8 ha), it was decided to remove Top Burrows, which had an area of 3.47 ha, from the Farm Platform in 2013, in order for all farmlets to be of a similar size. Additional French Drains were constructed to intercept and divert water draining from Top Burrows away from Flume 4. The changes to the Burrows Catchment are shown in Figure 14. In addition, the shape of the Burrows field changed shape slightly and as a result, this decreased in area from 6.5 ha to 6.4 ha and these changes were effected from 13 August 2013 onwards. Therefore, any data before 13 August 2013 relates to the 'old' Burrows configuration, including Top Burrows. It is important that this change is taken into consideration when using any data pre- or post- 13 August 2013 relating to Flume 4 or the fields contributing to this catchment.

Figure 14. Changes to field contributing to Burrows Catchment (Flume 4).

Original Burrows Flume 4 Fields, consisting of Bottom Burrows, Burrows and Top Burrow. The magenta lines represent the French drains flowing into Flume 4

Post Top Burrows split off Flume 4 Fields, consisting of Bottom Burrows and Burrows. The magenta lines represent the French drains flowing into Flume 4

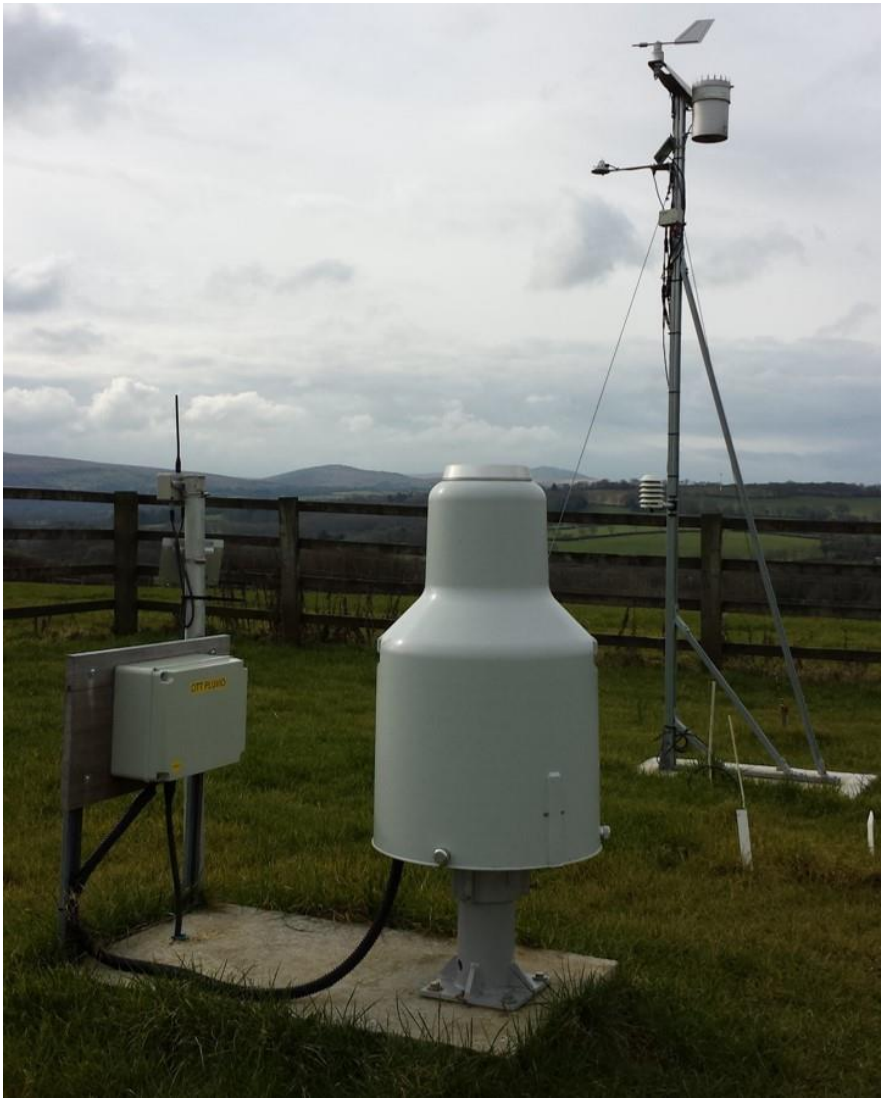
4.2 Division of Orchard Dean Catchment (Flume 5)

Catchment 5 (Orchard Dean) was originally constructed as one field as shown in Figures 3 and 14. However, in 2015 two fields (Orchard Dean North; NW045 and Orchard Dean South; NW046) were created by the construction of a new fence as shown in Figures 1, 4 and 16. The areas of these fields are shown in Table 1. The reason for this split, which was effected from 13 August 2015 onwards, was to create seven fields in each farmlet and facilitate the grouping of triplets of field enterprises (cattle grazing, sheep grazing, cutting).

5 Installation of Dedicated Meteorological Instruments

In April 2013, May 2014 and April 2015, meteorological equipment was installed to record precipitation (mm), air temperature (ºC), relative humidity (%), wind speed (km/h), wind direction (in degrees; installed April 2013) and solar radiation (W/m^2; installed in May 2014) at 15 min intervals. A more accurate Pluvio rain gauge was installed in April 2015 that can provide precipitation (mm) data at 1 min intervals (but currently not exported as such) and complements the data recorded by the tipping bucket rain gauges on the catchments (Figure 15).

Figure 15. Dedicated Meteorological Instruments



6 Moving from Baseline to Post-Baseline Managements

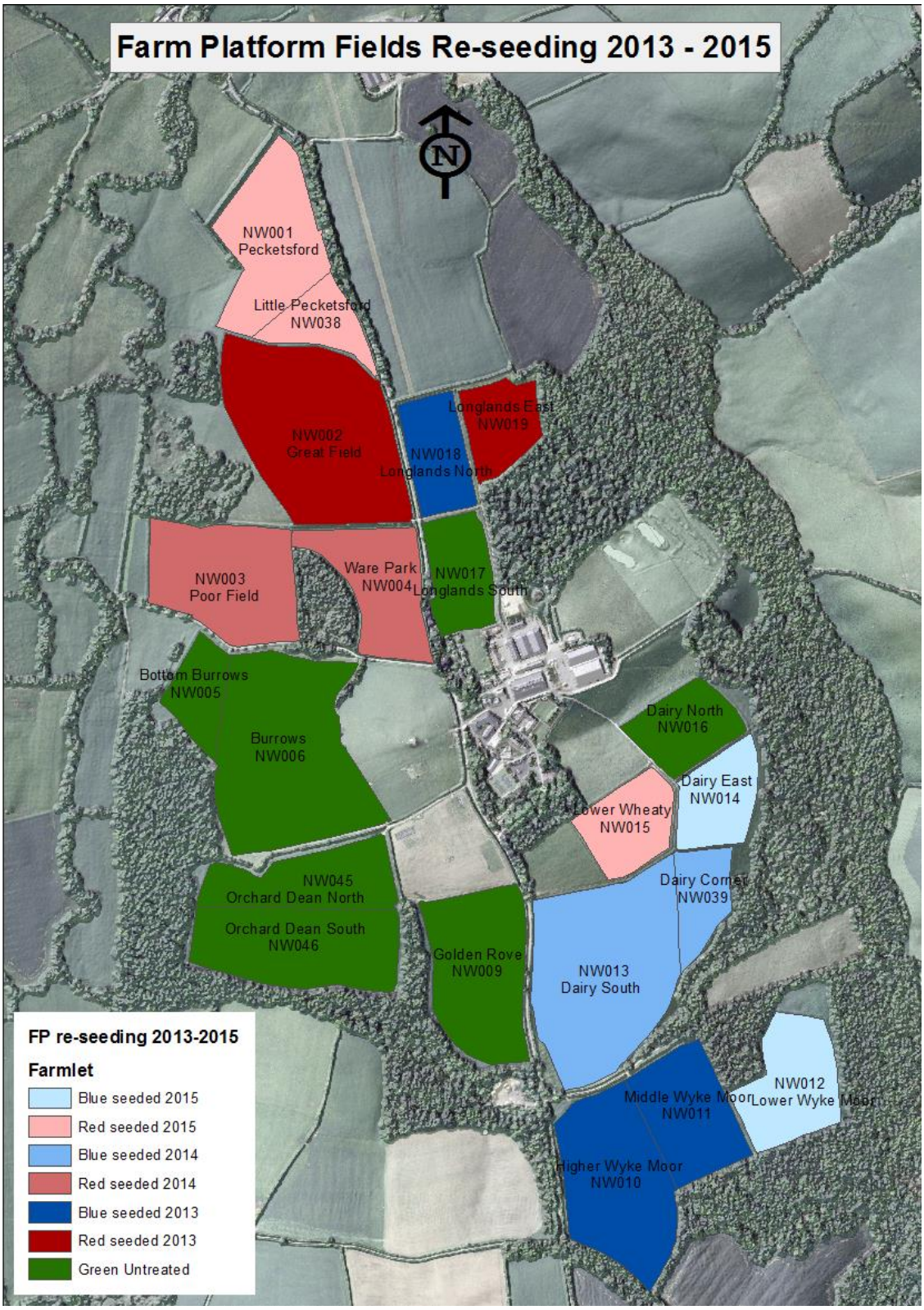
Over a two-year period from 1 April 2011 to 31 March 2013, beef and sheep systems were operated using the same management guidelines on the three farmlets in order to measure baseline productivity on the existing permanent pasture.

From 1 April 2013, the farmlets entered a phase where they progressively moved towards the following (post-baseline) treatments:

1. Green Farmlet (Permanent Pasture): continued use of the existing existing permanent pastures supplied with artificial fertilisers.
2. Blue Farmlet (Legumes): sowing grass and legume mixtures intended for long-term use. Clover based systems can replace up to 150 kg N ha^{-1} of industrially produced nitrogen, contribute to high protein and high digestibility forage, have high animal intake and performance, and are suitable for both grazing and conservation.
3. Red Farmlet (planned reseeding): regular reseeding with innovative grass varieties/traits (currently high sugar grasses, deep rooting grasses).

The farmlets assigned to the three treatments were shown in Figure 1. Individual catchments within the re-seeded farmlets were ploughed and re-seeded in 2013, 2014 or 2015 (Figure 16) with either perennial ryegrass (AberMagic), perennial ryegrass (AberMagic) + white clover (AberHerald), festulolium (Prior) or festulolium (Prior) + white clover (AberHerald). Thus, the transitional phase from baseline to post-baseline covered the 28-month period 1 April 2013 to August 31 2015. Detailed information on all field event and livestock management is given in FP_UG.Doc.004_FieldEvents&LivestockData.

Figure 16. Reseeding schedule from 2013-2015



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Appendix 1 Timeline of key events for NWFP construction and continued development

Date	Event
Construction	
August 2008	Drainage Survey
September 2008	Topographic Survey: >6000 points
October 2008	Hydrological Design [Draft report v5 (31 Oct 08).pdf]
August 2009	Revised flow estimates [Revised flow estimates (18 Aug 09).doc]
August 2009	EA Flood Defence Consent received
September 2009	Badger Survey
October 2009	Extended Phase 1 Habitat Survey
October 2009	Tree Species & Condition Survey
December 2009	Environmental Impact Assessment
March 2010	Planning Consent given
May – October 2010	Construction of French Drains and Flumes
July - August 2010	Fencing & Tracks completed
August – December 2010	Mains electricity and fibre-optic IT infrastructure installed
February – March 2011	Flume cabins installed
Sensors and Data Collection	
April 2011 – October 2011	Data sensors and telemetry equipment installed
05 January 2011	Start of collection of field event data
21 March 2011	Start of collection of livestock data
31 October 2011	Start of collection of soil moisture data
01 October 2012	Start of collection of water flow and properties
April 2013	Dedicated meteorological instruments installed
26 April 2013	Start of collection of meteorological data for whole site
31 March 2013	End of baseline data collection
May 2014	Solar radiation sensor added to meteorological site
April 2015	Pluvio rain gauge added to meteorological site
7-14 September 2015	Pressure transducers installed to replace bubbler flowmeters
June – November 2015	Adcon Soil Moisture Sensors - A51760 model replaced with A51730 model
4 Feb 2015	Phosphax analysers measuring both total and ortho-phosphate from here onwards
May- September 2016	Upgrade of YSI 6600V2 multi-parameter sonde to YSI Exo. Turbidity units changed from NTU to FNU. New loggers installed. Everything up and running by 29/10/16.
Land Management	
01 April 2013	Lower Wheaty and Longlands North swapped treatments

13 August 2013	Change in area of Catchment 4 (Burrows)
July-August 2013	Reseeding of Red farmlet catchments: 2 (Great Field) with AberMagic 15 (Longlands East) with Festulolium (Prior)
	Reseeding of Blue farmlet catchments: 8 (Higher & Middle Wyke Moor) with AberMagic & AberHerald 14 (Longlands North) with Festulolium (Prior) & AberHerald
July-August 2014	Reseeding of Red farmlet catchments: 3 (Poor Field & Ware Park) with AberMagic
	Reseeding of Blue farmlet catchments: 9 (Dairy South & Dairy Corner) with AberMagic & AberHerald
July-August 2015	Reseeding of Red farmlet catchments: 1 (Little Pecketsford & Pecketsford) with AberMagic 10 (Lower Wheaty) with AberMagic
	Reseeding of Blue farmlet catchments: 7 (Lower Wyke Moor) with AberMagic & AberHerald 11 (Dairy East) with AberMagic & AberHerald