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PHOSPHORUS EXPORTS FROM AGRICULTURAL GRASSLAND IN OVERLAND FLOW AND SUBSURFACE DRAINAGE WATER

Volume 2

A thesis submitted to the University of Dublin in fulfilment of the requirements for the degree of Doctor of Philosophy

by Isabelle Kurz, M.Sc.

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and
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Figure 1.1: Sampling Sites at Johnstown Castle

Overland Flow Sites

- High soil P (Cowlands)
- Medium soil P (Warren 2)
- Low soil P (Warren 1)

Stream at Dairy Farm

- Upstream monitoring station (M1)
- Downstream monitoring station (M2)

Artificial Subsurface Drainage (Beef Unit)

- Monitoring station (MB)

E.P.A. Environmental Protection Agency

Dept. Ag Department of Agriculture Food & Rural Development

Lakes / streams

Study area

Reference Map
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Figure 3.2: BEEF UNIT Soils
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<table>
<thead>
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<th>Map Unit</th>
<th>Texture</th>
<th>Drainage</th>
<th>Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Coarse loamy over fine loamy</td>
<td>Well</td>
<td>Brown Earth</td>
</tr>
<tr>
<td>B1</td>
<td>Sandy</td>
<td>Well</td>
<td>Brown Podzolic / Brown Earth</td>
</tr>
<tr>
<td>C3</td>
<td>Coarse loamy over fine loamy</td>
<td>Poor</td>
<td>Gley</td>
</tr>
<tr>
<td>A2</td>
<td>Fine loamy</td>
<td>Imperfect</td>
<td>Gley</td>
</tr>
<tr>
<td>A3</td>
<td>Fine loamy</td>
<td>Poor</td>
<td>Gley</td>
</tr>
</tbody>
</table>
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Soil P index as defined by Teagasc (Coulter, 2001)

- P Index 1 (0 - 3 mg/l)
- P Index 2 (3.1 - 6.0 mg/l)
- P Index 3 (6.1 - 10 mg/l)
- P Index 4 (> 10.0 mg/l)

Catchment boundary
Monitoring station
Roadway

0.1 0 0.1 0.2 Kilometres
Figure 3.4: DAIRY UNIT Soils
(Culleton and Diamond, in print)

<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Texture</th>
<th>Drainage</th>
<th>Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Brown Earth</td>
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<tr>
<td>A2</td>
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<td>Imperfect</td>
<td>Gley</td>
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<td>A3</td>
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<td>Sandy</td>
<td>Well</td>
<td>Brown Podzolic / Brown Earth</td>
</tr>
<tr>
<td>B2</td>
<td>Sandy</td>
<td>Moderate</td>
<td>Brown Earth</td>
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<tr>
<td>C1</td>
<td>Coarse loamy over fine loamy</td>
<td>Well</td>
<td>Brown Earth</td>
</tr>
<tr>
<td>C2</td>
<td>Coarse loamy over fine loamy</td>
<td>Moderate / imperfect</td>
<td>Gley</td>
</tr>
<tr>
<td>C3</td>
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<td>Poor</td>
<td>Gley</td>
</tr>
</tbody>
</table>
Soil P index as defined by Teagasc (Coulter, 2001)

- **P Index 1** (0 - 3 mg / l)
- **P Index 2** (3.1 - 6.0 mg / l)
- **P Index 3** (6.1 - 10 mg / l)
- **P Index 4** (> 10.0 mg / l)

- Subcatchment boundary
- Monitoring station (M1, M2)
- Bogwood.
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- Monitoring stations (M1, M2)
- Artificial subsurface drains
- Dairy sub-catchment boundary
- Stream underground
- Contour lines (1m intervals, height above sea level)
- Dairy farm outline
- Bogwood
- Arrow indicates subsurface drains leading to outside sub-catchment
- Arrow indicates the direction of flow

0.2 0 0.2 0.4 Kilometres
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Stream underground
Stream above ground
Springs
Monitoring stations
MB Beef Unit (subsurface water)
M1 Upstream station Dairy Farm
M2 Downstream station Dairy Farm
Grab sampling stations
G1 Spring upstream Bogwood
G2 At weir
G3 Stream access hole at Dairy Farm
G3 D1 Subsurface drain at access hole
G3 D2 Subsurface drain at access hole
G3 O Overland flow at access hole
A1 Drain at Beef Unit
A2 Tank at Beef Unit
A3 Stream access hole at castle wall
A4 End of Bogwood
X Pipe at Beef Unit
XR Overland flow from road
Old mill
Dairy Farm sub-catchment boundary
Beef Unit catchment boundary
Bogwood
Rivers / Lakes
Farmyards
B1 Farmyard Beef Unit: Buildings
B1 Farmyard Beef Unit: Silage pits
B2 Farmyard Dairy Farm: Buildings
B2 Farmyard Dairy Farm: Silage pits
Roads

0.3 0 0.3 0.6 Kilometres
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Water level in reference to the ground (cm)

Date

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- Overland flow collection drain
- Open drain
- Water table tubes
- Contour lines at 1m intervals (local datum, Ryan 1998)
- Underground drain to flow monitoring and water sampling station

Legend:
- A1, A2, A3, A4
- B1, B2, B3, B4
- C1, C2, C3, C4
- D2, D3, D4
- E3, E4

Contour lines at 1m intervals (local datum, Ryan 1998)

Spring

Scale: 20 0 20 40 Metres
Figure 7.2 Site Map of the Cowlands (adapted from Ryan 1998)

- Berm
- Open drain
- Contour lines at 1m intervals (local datum, Ryan 1998)
- Water table tubes
- Underground drain to flow monitoring and water sampling station
- Overland flow collection area
Figure 7.3: Site Map of the Warren 2

- Berm
- Open drain
- Water table tubes
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Date/Time (American style)
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![Graph showing flow and DRP/TP concentrations over time.](image-url)
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Date/Time (American Style)

Flow (l/s)

mg P/l
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Conductivity (μS/cm)

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Figure 9.26: Low flow grab sampling December 1996 to end of January 1997: DRP concentrations (mg P/l) of samples taken at the stream access hole at the castle wall (A3), at the end of the Bogwood (A4) at the weir (G2), at the stream access hole in the middle of the Dairy Farm (G3), at the upstream (M1) and at the downstream (M2) monitoring stations.
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Plate 4.2: Evenly coloured topsoil at site Dye 1.
Plate 4.3: Vertical coloured tongues divided by uncoloured areas below the topsoil at site Dye 1.

Plate 4.4: Bleached zones penetrated by roots at site Dye 1.
Plate 4.5: Dye distribution down the soil profile at site Dye 2.

Plate 4.6: Unevenly coloured topsoil at site Dye 2.
Plate 4.7: A large macropore (inside white rectangle) forms the centre of a coloured finger extending down the soil profile.
Plate 4.8: Double ring infiltrometer (from Diamond and Shanley, in print).
Buchner flask with rubber bung

Suction pump

Bentonite seal

50mm

45°

Backfilled in situ soil 160-600mm

(Soil)

Silica slurry

Teflon suction cup (20mm dia.)

Plate 8.1: Teflon suction cup installed as specified in Section 8.2.2.
Plate 8.2: Zero-tension sampler installed as specified in Section 8.2.2.
Appendix 1: Soil Profiles

**Dye 1**

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Description</th>
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<tbody>
<tr>
<td>0 - 20</td>
<td>Sandy loam; dark yellowish brown (10YR 3/4) with few, very fine, prominent, sharp, yellowish red (5YR 4/6) mottles; weakly developed medium granular structure; moderately weak consistence, semi-deformable; moderately plastic, slightly sticky; slightly stony with very small to medium angular tabular to rounded stones; very fine and fine vertical to horizontal pores (2%); many fibrous, very fine and fine roots; smooth, abrupt boundary to</td>
</tr>
<tr>
<td>20 - 50</td>
<td>Loamy sand; brownish yellow (10YR 6/8) and dark yellowish brown (10 YR 4/6) with common, very fine, distinct, sharp, black (7.5YR 2/0) and reddish yellow (5YR 6/8) mottles; weakly developed medium subangular blocky structure; very weak consistence, semi-deformable, non-plastic, not sticky; slightly stony and bouldery with very small to very large stones subangular platy to rounded stones; very fine and fine vertical to horizontal pores (0.5%); few fibrous, very fine and fine roots; smooth, sharp boundary to</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>Loam; strong brown (7.5YR 4/6) and pink (5YR 7/3) with common, very fine and fine, prominent, sharp, black (2.5YR 2.5/0) mottles; moderately developed, coarse, angular blocky structure; moderately firm consistence, deformable, very plastic, moderately sticky; very slightly stony with very small, subrounded tabular to rounded stones; very fine, vertical to horizontal pores (0.1%); few fibrous, very fine roots.</td>
</tr>
</tbody>
</table>

**Dye 2**

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td>Sandy loam; brown to dark brown (10YR 4/3) with common, fine, distinct, sharp, black (2.5YR 2.5/0) and brown to dark brown (7.5YR 4/4) mottles; weakly developed, fine to medium granular structure; moderately weak consistence, semi-deformable, slightly plastic, non-sticky; slightly stony with very small to medium stones platy and angular subrounded to rounded stones; very fine to medium, vertical to horizontal pores (2%); common, very fine to medium, fibrous and fleshy roots; sharp smooth boundary to</td>
</tr>
<tr>
<td>&gt; 30 - (70-100)</td>
<td>Sandy loam; yellowish brown (10YR 5/4) with many coarse, distinct, clear, dark brown (7.5YR 3/2) mottles; weakly developed very coarse subangular blocky structure; moderately weak consistence, semi-deformable, not plastic, non-sticky; slightly stony with very small to medium subangular to rounded stones; very fine to medium, mainly vertical pores; few, very fine to medium fibrous and fleshy roots; smooth and boundary to</td>
</tr>
<tr>
<td>&gt; (70 - 100)</td>
<td>Loamy sand; light grey (10YR 7/2) and strong brown (7.5YR 5/8) with common, coarse, distinct, clear black (2.5YR 2.5/0) mottles; weakly developed, coarse subangular blocky structure; very weak consistence, semi-deformable, slightly plastic, non-sticky; very slightly stony with very small, subangular platy stones; mainly very fine and some fine vertical to horizontal pores (0.5%); few very fine fibrous roots.</td>
</tr>
<tr>
<td>Depth cm</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>0-20</td>
<td>Loam; brown to dark brown (10YR 4/3) with common, yellowish brown (10YR 5/6), extremely fine to medium, distinct and sharp mottles; coarse granular, weakly developed structure; semi-deformable and slightly plastic; slightly stony with angular tabular very small to medium stones; 5% very fine to medium pores; sharp smooth boundary to</td>
</tr>
<tr>
<td>20-22/40</td>
<td>Loamy sand; light grey (2.5Y 7/2) with common, very pale brown (10YR 7/4), yellow (10YR 7/8) and black (2.5YR 2.5/0), prominent, very fine to coarse, clear and diffuse mottles; massive structure; brittle and non-plastic consistence; very slightly stony with most very small and some medium subangular rounded stones; 0.5% very fine to fine pores; few very fine fibrous roots; sharp tongued boundary to</td>
</tr>
<tr>
<td>&gt;22/40</td>
<td>Clay; strong brown (7.5YR 5/6) and light grey (10YR 7/2) with very few, very fine, distinct, sharp (2.5YR 2.5/0) mottles; weakly developed, subangular blocky, very coarse structure; deformable and moderately plastic consistence; very slightly stony with very small angular platy stones; 0.5% very fine and fine random pores; few very fine, fibrous and very few fine wooden roots.</td>
</tr>
<tr>
<td>Date</td>
<td>DRP (mg P/I)</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
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<tr>
<td>24-Jan-97</td>
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<tr>
<td>31-Jan-97</td>
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<tr>
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<tr>
<td>04-Feb-97</td>
<td>0.016</td>
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<tr>
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<tr>
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<tr>
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<tr>
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<th>TDP (mg P/I)</th>
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### Appendix 3

TDP concentrations in samples from Teflon suction cups.

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<th>Event (sampling date)</th>
<th>Sampler ID</th>
<th>TDP (mg P/l)</th>
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<tbody>
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<tr>
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<tr>
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<td>T4</td>
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<tr>
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<tr>
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<td>T6</td>
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</tr>
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<td><strong>BU3 (18th November 1997)</strong></td>
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<tr>
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<td>T3</td>
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<tr>
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