# Crymlyn Tip, Coed Darcy, Llandarcy

## Landfill Gas Risk Assessment and Gas Management Plan

St Modwen Developments Ltd

**June 2013**

Plan Design Enable

# Notice

This document and its contents have been prepared and are intended solely for St Modwen Developments Ltd's information and use in relation to the Crymlyn Tip, Coed Darcy, Llandarcy.

Atkins assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 23 pages including the cover.

## Document history

| **Job number: 5041216** | | | **Document ref:** | | | |
|---|---|---|---|---|---|---|
| Revision | Purpose description | Originated | Checked | Reviewed | Authorised | Date |
| Rev 0 | Draft for Client Review | AKA | MN | RM | RM | June 2013 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## Client signoff

| | |
|---|---|
| Client | St Modwen Developments Ltd |
| Project | Crymlyn Tip, Coed Darcy, Llandarcy |
| Document title | Landfill Gas Risk Assessment and Gas Management |
| Job no. | 5041216 |
| Copy no. | n/a |
| Document reference | |

# Table of contents


| Chapter | Pages |
|---|---|
| **1. Introduction** | **1** |
| 1.1. Report Context | 1 |
| 1.2. Conceptual Site Model – Landfill Gas | 1 |
| **2. Landfill Gas Risk Assessment** | **3** |
| 2.1. The Nature of the Landfill Gas Risk Assessment | 3 |
| 2.2. The Proposed Assessment Scenarios | 3 |
| 2.3. Numerical Modelling | 4 |
| 2.4. Risks to the Environment and Human Health | 5 |
| **3. Landfill Gas Management Plan** | **13** |
| 3.1. Control Measures | 13 |
| 3.2. Monitoring and Sampling Plan | 13 |
| **4. Conclusions** | **14** |
| 4.1. Compliance with the Landfill Directive 1999 | 14 |
| **5. References** | **15** |
| **Appendices** | **16** |
| **Appendix A. Environment Agency Qualitative Risk Screening Tables** | **17** |
| **Appendix B. Gas Emissions Graphs** | **19** |
| B.1. In-landfill | 19 |
| B.2. Non-landfill (west) | 19 |
| B.3. Non-landfill (east) | 19 |
| B.4. Off-site (east) | 19 |
| B.5. Off-site (south) | 19 |


## Tables


| | | |
|---|---|---|
| Table 1–1 | Landfill Gas Receptors | 2 |
| Table 1–2 | Lateral migration environmental benchmarks | 2 |
| Table 1–3 | Prioritisation of Receptors | 2 |
| Table 2–1 | Risk assessment table | 4 |
| Table 2–2 | Justification of likelihood scores | 4 |
| Table 2–3 | Summary of methane exceedances within landfill | 5 |
| Table 2–4 | Summary of carbon dioxide exceedances within landfill | 7 |
| Table 2–5 | Summary of methane exceedances within non-landfill (west) area | 8 |
| Table 2–6 | Summary of carbon dioxide exceedances witin non-landfill (west) area | 9 |
| Table 2–7 | Summary of carbon dioxide exceedances within off-site (east) area | 10 |
| Table 2–8 | Summary of methane exceedances within off-site (south) area | 10 |
| Table 2–9 | Summary of carbon dioxide exceedances within off-site (south) area | 11 |
| Table 4–1 | Environment Agency likelihood categories | 17 |
| Table 4–2 | Environment Agency severity categories | 17 |
| Table 4–3 | Severity likelihood matrix | 17 |
| Table 4–4 | Risk evaluation | 18 |

# 1. Introduction

## 1.1. Report Context

Atkins Ltd (Atkins) has been commissioned by St. Modwen Developments Ltd (SMD) to produce a Landfill Gas Risk Assessment Report (LFGRA), in general compliance with an environmental permit (EPR/AP3990LR) held by SMD for the Crymlyn Tip on the Coed Darcy site, Llandarcy, Port Talbot.

This report has been prepared in general accordance with the Environment Agency's "Landfill Gas Risk Assessment Report" template and based on supporting information relating to the site collected by Atkins since 2010.

This report should be read in conjunction with the ESID Report which accompanies this LFGRA. An outline of the proposed installation and historical operations undertaken at this site is contained in Section 1.2 of the ESID Report of the partial surrender application.

In summary the landfill, according to Schedule 1 of the environment permit, is recorded as A07 – In-house landfill (Closed). Therefore activities currently undertaken on and around the site relate solely to improvement of the condition of the land and any discharges from the land. The site has not accepted waste since 1999 and has officially been non-operational since July 2001. There are no known historical areas of landfill or former waste management licences adjacent to or within 1km of the site.

## 1.2. Conceptual Site Model – Landfill Gas

### 1.2.1. Sources

The landfill accepted waste between 1974 and 1999 and was formally closed in 2001. The site is regulated under the environmental permit number EPR/AP3990LR. A detailed account of the waste streams historically accepted at the landfill can be found in Section 2.1.1 of the ESID which accompanies this document. The precise volumes of placed waste are unknown. The waste historically placed within the landfilled area, located in the eastern half of the permitted zone, was predominantly non-putrescible, including oily sludge waste.

The landfill is unlined with waste deposited directly onto the superficial deposits, including Peat deposits. It is understood that the permitted area has been subject to contamination by free-phase hydrocarbons emanating from the southern tank farm related to the refinery historically located south of the site. Emissions of gas, namely methane and carbon dioxide, are therefore likely to result from degradation processes of the free-phase hydrocarbons both within the waste mass (landfill gas) and from the historically contaminated land (ground gas). It is also highly probable that biodegradation processes occurring within the underlying Peat deposits will release ground gases.

### 1.2.2. Pathways

Numerous pathways exist to facilitate exposure of receptors to emissions of landfill gas. The Environment Agency (Environment Agency, 2004) has identified the following generic potential pathways:

- Direct release to atmosphere;
- Sub-surface migration, through the ground or along man-made services;
- Indirect release to atmosphere, for example from sub-surface landfill gas migration, or dissolution from leachate and condensate; and
- Discrete point releases and fugitive emissions occurring intermittently during excavations and well drilling.

### 1.2.3. Receptors

The key receptors are summarised in Table 1–1 below.

**Table 1–1 Landfill Gas Receptors**

| Receptor group | Receptors | Distance and bearing from permitted site |
|---|---|---|
| Domestic dwellings | Demonstration village | 0m to the south |
| Sensitive Habitats | Crymlyn Bog (SSSI, SAC, NNR, Ramsar) | 20m to the west |

### 1.2.4. Environmental Assessment Limits (EAL)

Environmental benchmarks have been selected for sub-surface lateral migration based on default limits established by the Environment Agency in their draft 'Guidance on the Management of Landfill Gas 2004' (Environment Agency, 2004). The relevant trigger levels used to screen gas monitoring data is summarised in Table 1–2. This method of screening is deemed as appropriate by Atkins and no further quantification of air dispersion and emission will be required.

**Table 1–2 Lateral migration environmental benchmarks**

| Emission | EAL (%v/v) | |
|---|---|---|
| | Control level | Trigger level |
| Methane | 0.5% | 1.0% |
| Carbon Dioxide | 1.0% | 1.5% |

#### 1.2.4.1. Receptor Prioritisation and Impact Assessment

Prioritisation of the receptors identified in Section 1.2.4 has been undertaken following Environment Agency guidance (Environment Agency, 2004) and involves a qualitative assessment of the sensitivity of the receptor and the likelihood of exposure, as sumamrised in Table 1–3 below.

**Table 1–3 Prioritisation of Receptors**

| Receptor | Hazard | Sensitivity of receptor | Likelihood of exposure | Assigned priority |
|---|---|---|---|---|
| Demonstration Village | Fire and explosion, toxicity, asphyxiation and odour. | High | Somewhat unlikely | 2 |
| Crymlyn Bog | Toxicity and eco-toxicity | High | Somewhat unlikely | 2 |

# 2. Landfill Gas Risk Assessment

## 2.1. The Nature of the Landfill Gas Risk Assessment

A landfill gas risk assessment (LfGRA) is required to assess the impact of Crymlyn Tip on the nearby receptors identified in Section 1.2.3. The principal objectives of the LfGRA are as follows;

- Identify plausible background concentrations of landfill/ ground gases;
- Based on the Conceptual Site Model (CSM), establish if a risk exists to key receptors; and
- Determine whether the presence of landfill material has affected receptors or has the potential to do so.

Atkins have undertaken gas monitoring since 2010 to determine the concentration of the following key parameters;

- Methane – peak concentration as %v/v;
- Carbon Dioxide – peak concentration as %v/v;
- Carbon Monoxide – peak concentration as %v/v;
- Oxygen – peak concentration as %v/v;
- Relative Pressure;
- Flow in litres/ hr within the borehole;
- Atmospheric Pressure; and
- Weather Conditions.

The results can be found in Appendix ESID3 of the ESID Report.

The choice of the most appropriate level of risk assessment is dependent upon the level of risk and uncertainty to Crymlyn Tip. A Tier 2 'simple' risk assessment which examines the source-pathway-receptor links using a mixture of site-specific data and projections of site performance has been applied in accordance with Environment Agency guidance (Environment Agency, 2004). This approach is justified as the potential source, pathway and receptor terms and can be defined with sufficient certainty such that they can be confidently represented by conservative inputs, models and assumptions.

## 2.2. The Proposed Assessment Scenarios

### 2.2.1. Lifecycle Phases

The three major lifecycles applicable to a landfill are: the operational phase (land filling), post-operational phase and completion (end of gas producing life). The landfill accepted waste relating to Llandarcy Refinery between 1977 and 1999. As the landfill is no longer accepting waste, the operational phase has not been considered further.

### 2.2.2. Accidents and their Consequences

Assessment of the magnitude of impact caused by a number of potential accident and failure scenarios is a necessary component of the risk assessment process. The Environment Agency has suggested the following generic accident and failure scenarios:

- Loss of containment;
- Loss of collection and/or treatment capability;
- Deep-seated landfill fire; and
- Failure of waste input screening procedures and controls.

These scenarios have been qualitatively assessed with the results shown in Section 2.2.2.1.

#### 2.2.2.1. Qualitative Assessment

The results of the qualitative risk assessment process are presented in Table 2–1 below. Risk assessment has been undertaken following Environment Agency guidelines (Environment Agency, 2004) with determination of likelihood, severity and risk based on standard tables reproduced in Appendix A.

**Table 2–1 Risk assessment table**

| Scenario | Likelihood | Severity | Score | Magnitude of Risk |
|---|---|---|---|---|
| Landfill fire | Very unlikely (2) | Significant (3) | 6 | Insignificant |
| Loss of containment | Extremely unlikely (1) | Minor (1) | 1 | Insignificant |
| Loss of collection/ treatment | Extremely unlikely (1) | Minor (1) | 1 | Insignificant |

Justifications for the assignment of likelihood scores for each of the accident and failure scenarios identified are detailed in Table 2–2 below.

**Table 2–2 Justification of likelihood scores**

| Landfill fire | Likelihood score justification |
|---|---|
| Landfill fire | No active gas abstraction systems have been specified and as such there is minimal chance of drawing air into the landfill to fuel the landfill fire. |
| Loss of containment | The site has no engineered containment system. |
| Loss of collection/ treatment | No collection system design is currently in place. |
| Biodegradable waste input | No additional wastes are to be introduced into the landfill. |

Since the site is no longer accepting waste, further quantitative analysis will assess the risk of gas migration from within the waste mass to the surface based on the historical gas concentrations monitored across the permitted site between 2010 and 2013.

Following an initial assessment of the gas monitoring data in the ESID Report (Section 3.6 of ESID Report) the following landfill gases have been identified as being present at the site during historical monitoring of the landfill and are the subject of further assessment:

- Methane; and
- Carbon dioxide.

The ESID Report also indicates that carbon monoxide and hydrogen sulphide are restricted to the in-landfill area in the east of the site.

## 2.3. Numerical Modelling

Numerical modelling has not been carried out for the Crymlyn Tip as landfilling activity has ceased and therefore the volumes of landfill gas being emitted are not anticipated to increase, but will presumably reduce over time.

# 2.4. Risks to the Environment and Human Health

## 2.4.1. Landfill Gas Emissions

Given the age of the site and absence of gas monitoring data prior to the installation of the landfill it is not possible to provide a historical baseline landfill gas analysis.

Monitoring of landfill gas has been carried out since 2010 within the permitted area at a total of 41 boreholes across the permitted area and the immediate surroundings. For the purposes of analysis, the site has been separated into 5 sections;

- in-landfill (i.e. the eastern half of the permitted area);
- non-landfill (west) (i.e. the western half of the permitted area);
- non-landfill (east) (i.e. the area not landfilled in the far east of the site);
- off-site (east); and
- off-site (south).

The gas monitoring data are in Appendix ESID3 of the ESID Report. Monitored methane and carbon dioxide gas data has been screened against a 1% and 1.5% trigger level respectively, in-line with the Environment Agency guidance (as described in Section 1.2.4). Each zoned area has been assessed to provide a site-wide overview of potential gas migration, and the results are presented below.

### 2.4.1.1. In-landfill

Gas monitoring was undertaken on 3 occasions in October and November 2010, and on 3 occasions in April and May 2013 at 26 boreholes within the landfilled area. The 11 boreholes which exceeded the trigger level for methane concentration are highlighted in Table 2–3 below, exceedances of the 1% trigger level are highlighted in grey.

**Table 2–3 Summary of methane monitoring within landfill**

| Borehole | 12/10/2010 | 25/10/2010 | 17/11/2010 | 19/04/2011 | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CARW024 | 0.6 | 0.8 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 |
| CBH 2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.2 |
| CBH 20 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 34.7 | 34.9 | 39.1 |
| CBH 31 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 44.7 | 33.2 | 45.8 |
| CBH 33 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 2.8 | 0 | 0.3 |
| CBH 36 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 3.2 | 0 | 0.1 |
| CBH 37 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.8 | 0.2 | 0.1 |
| CBH 4 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.3 | 0.4 | 0.6 |
| CBH 41 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 11.6 | 63.9 | 46.8 |
| CBH 42 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 18 | 53.2 | 84.4 |
| CBH 48 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 8.7 | 2.5 | 11.7 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CBH 58 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.5 | 0 | 0.1 |
| CBH 63 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.1 |
| MSMW033D | 0.1 | 0 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW033S | 0 | 0 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW034 | 0.1 | 0.1 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW034D | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.1 |
| MSMW035D | 0 | 0 | 0.1 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.1 |
| MSMW035D2 | 0 | 0 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.1 |
| MSMW035S | 0 | 0 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 0.1 |
| MSMW152D | 0.1 | 0.1 | 0 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW228 | 0.1 | 0.1 | | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW235 | 15.9 | 13 | 16.4 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 20.8 | 20.4 | 22.9 |
| MSMW236 | 2.4 | 44.6 | 0.1 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 11.5 | 16.1 | 22.2 |
| MSMW238 | 0.7 | 5.2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 39 | 34.8 | 34.9 |
| MSMW239 | 0.1 | 0.3 | | | | | | | | | | |

Concentrations measured as %v/v

‘borehole not monitored.

The highest concentration of methane was 84.4%v/v detected at CBH42. Most boreholes showed no real alteration in concentration between 2010 and 2013, with the exception of MSMW238, which exhibited a large increase in concentration from an average of 3.0%v/v in 2010 to 36.2%v/v in 2013 (as shown in graph 1 in Appendix B.1). All sites at which the trigger level was exceeded are located within the central area that is known to have hydrocarbons present as indicated in borehole logs (Appendix ESID1 of the ESID Report) and as shown in drawing ESID13. It is also understood that this was a site of sludge deposition. The boreholes in which gas was not detected were generally located outside of the leachate affected areas, approximately at the fringes of the landfilled area and at greater depths. Gas concentrations at almost all boreholes appear highly variable over the monitoring period, several boreholes further west and further east of the main leachate area remain fairly constant, such as CBH2 and CBH4 (west) and CBH63 and MSMW035S, as shown in graph 2 in Appendix B.1.

The carbon dioxide concentration was found in exceedance of the 1.5% trigger level at 18 boreholes. A summary of the locations where exceedances of the trigger level occurred are highlighted in grey in Table 2–4 below.

**Table 2–4 Summary of carbon dioxide monitoring within landfill**

| Borehole | 12/10/2010 | 25/10/2010 | 17/11/2010 | 19/04/2011 | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CARW024 | 2 | 3.5 | 6 | 0.6 | 0.3 | 0.7 | 0.4 | 0.1 | 0.1 | 0 | 0.4 | 0 |
| CBH 2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0.1 | 0.8 |
| CBH 20 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 8.6 | 9.1 | 9.4 |
| CBH 31 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 4.6 | 5.6 | 4.2 |
| CBH 33 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 7.7 | 0 | 0 |
| CBH 36 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 9.7 | 0 | 0 |
| CBH 37 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 5.7 | 0.6 | 0 |
| CBH 4 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0.2 | 0.1 |
| CBH 41 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 2.5 | 3 | 2.6 |
| CBH 42 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 1.7 | 5.3 | 2.2 |
| CBH 48 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 7.6 | 4.3 | 8.7 |
| CBH 58 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 2.7 | 0.2 | 0 |
| CBH 63 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 11.1 | 2.9 | 1.9 |
| MSMW033D | 1.6 | 2 | 1.9 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW033S | 0 | 0.2 | 0.1 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW034 | 0.1 | 0.9 | 0.4 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW034D | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.1 | 0.2 | 0.6 |
| MSMW035D | 0 | 1 | 1.2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.1 | 0.3 | 0.8 |
| MSMW035D 2 | 0 | 0.4 | 0.2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.1 | 0.1 | 0.3 |
| MSMW035S | 0 | 0.2 | 0.6 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.3 | 2.2 | 1.7 |
| MSMW152D | 0 | 0.3 | 0.2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW228 | 0.7 | 9.1 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |
| MSMW235 | 11.5 | 12.1 | 8.8 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 9.7 | 9.5 | 9.4 |
| MSMW236 | 0.2 | 4.4 | 0.2 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 1.1 | 7.9 | 7.4 |

| Borehole | 12/10/2010 | 25/10/2010 | 17/11/2010 | 19/04/2011 | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSMW238 | 2.9 | 10.3 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 5.2 | 5.8 | 7 |
| MSMW239 | 0 | 3 | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ |

Concentrations measured as %v/v

‘borehole not monitored.

The highest concentration of 12.1%v/v was detected at MSMW235. Exceedances of the trigger level occurred at all monitored locations within the landfilled area with the exception of CBH2, CBH4, MSMW033S, MSMW034, MSMW034D, MSMW035D, MSMW035D2 and MSMW152D. The shallow installations within the waste mass appear to have the highest concentration of carbon dioxide; these depths are shown to correlate with the depths at which the borehole logs note the presence of hydrocarbons, such as MSMW034. Deeper boreholes installed within the bedrock, such as MSMW035D2, generally exhibit negligible gas concentrations. Gas concentrations at several boreholes, including CBH33, CBH36 and CBH58, appear highly variable over the 3 weeks of monitoring during April/ May 2013, as shown in graph (Appendix B.1).

#### 2.4.1.2. Non-landfill (west)

Gas monitoring was undertaken in 10 boreholes within the non-landfilled zone within the western section of the permitted area on eleven occasions between 2010 and 2013. The methane trigger level (1.5%v/v) was exceeded in all borehole locations on at least one occasion as summarised in Table 2–5 below.

**Table 2–5 Summary of methane monitoring within non-landfill (west) area**

| Borehole | 12/10/2010 | 25/10/2010 | 17/11/2010 | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CARW015 | ‘ | ‘ | ‘ | 40.5 | 14.2 | ‘ | 0.4 | ‘ | ‘ | ‘ | ‘ |
| CARW025 | ‘ | ‘ | ‘ | 90.6 | 73.8 | 99.9 | 90.8 | 0.2 | 31.6 | 17.4 | 20.5 |
| CARW029B | 0.2 | 1.3 | ‘ | 0.8 | 0 | 0.6 | 0.1 | 0.1 | 0 | 0 | 1.8 |
| GA7S | ‘ | ‘ | ‘ | 0 | 0 | 0 | 0.1 | 4.5 | 0.1 | 0 | 0.2 |
| MSMW027S | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0.1 | 0 | 0.1 |
| MSMW155D | ‘ | ‘ | ‘ | 0 | 0.3 | 0.2 | 0.1 | 0.1 | 0 | 0 | 0.1 |
| MSMW155S | ‘ | ‘ | ‘ | 0 | 0.9 | 3.6 | 2.9 | 0.2 | 0.9 | 0.1 | 0.1 |
| MSMW156D | 0.1 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0.1 |
| MSMW156S1 | ‘ | ‘ | ‘ | 0.4 | 3.5 | 5.7 | 2.9 | 3.6 | 0.5 | 0.1 | 0.1 |
| MSMW156S2 | ‘ | ‘ | ‘ | 5.8 | 34.2 | 0.8 | 34.1 | 0.9 | 0.2 | 0 | 17.4 |

Concentrations measured as %v/v

‘borehole not monitored.

The highest concentration was detected at CARW025, where a maximum of 99.9%v/v was detected in December 2011. The average concentration during 2011 monitoring was 88.1%v/v, whilst the average during 2013 monitoring was 23.2%v/v.

Overall there appears to have been a general decline over time in methane concentrations at all boreholes monitored, as shown in graph 6 (Appendix B.2). However the gas concentrations appear quite variable at several boreholes including MSMW156S1 and MSMW156S2.

The installations within CARW015, CARW025, CARW029B, GA7S, MSMW027S and MSMW156S1 are shown in their borehole logs to have either black staining and/ or a hydrocarbon odour approximately at the intake depth and is within the made ground; it is therefore considered likely that the gas emitted is due to the presence of historical hydrocarbon contamination rather than migration from the waste mass in the east of the permitted area.

Boreholes CARW015, CARW025 and MSMW156S2 exhibit a similar trend in methane concentration, as shown in graph 7 in Appendix B.2). All three locations have shallow Peat deposits at the intake section of the monitoring installation. It appears likely that a source of gas is influencing the three locations via the Peat deposits as a source. The source is likely to be ground gases emitted from the degradation of hydrocarbons from a historic spillage emanating from the southern tank farm which has been attenuated within the shallow Peat deposits at these locations, as described above.

Carbon dioxide was detected at concentrations in exceedance of the threshold value in all boreholes monitored, as summarised in Table 2–6.

**Table 2–6 Summary of carbon dioxide monitoring within non-landfill (west) area**

| Borehole | 12/10/2010 | 25/10/2010 | 17/11/2010 | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CARW015 | ‘ | ‘ | ‘ | 4.2 | 2.9 | ‘ | 2.7 | ‘ | ‘ | ‘ | ‘ |
| CARW025 | ‘ | ‘ | ‘ | 1.2 | 0.6 | 0.6 | 0.4 | 0.1 | 0.1 | 0.4 | 14.5 |
| CARW029B | 0.5 | 1.5 | ‘ | 2.3 | 0.6 | 2.1 | 0.2 | 0.2 | 0.3 | 0.1 | 0.05 |
| GA7S | ‘ | ‘ | ‘ | 0.9 | 1.3 | 3 | 4.3 | 2.4 | 0.1 | 0.3 | 0.7 |
| MSMW027S | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | ‘ | 0 | 0 | 2.8 |
| MSMW155D | ‘ | ‘ | ‘ | 0.4 | 1.8 | 1.3 | 1.5 | 0.3 | 0.2 | 0.4 | 0.1 |
| MSMW155S | ‘ | ‘ | ‘ | 0.1 | 0.5 | 1.1 | 1.5 | 0.1 | 0.1 | 0 | 1.2 |
| MSMW156D | 0 | 0.1 | 0.1 | 3.1 | 0.3 | 0.3 | 0.1 | 2.8 | 0 | 0.1 | 0 |
| MSMW156S1 | ‘ | ‘ | ‘ | 6 | 4.2 | 2.7 | 2.7 | 2.4 | 0.3 | 0.5 | 0.1 |
| MSMW156S2 | ‘ | ‘ | ‘ | 6.6 | 4.2 | 0.1 | 4.3 | 0.2 | 0 | 0 | 1.2 |

Concentrations measured as %v/v

‘borehole not monitored.

The highest concentration of carbon dioxide was detected at CARW025, where a maximum of 14.5%v/v was detected in May 2013. The concentrations of carbon dioxide appear variable at each monitored borehole, as shown in graph 8 (Appendix B.2). Flows were detected at this monitoring location ranging between 0 and 4.3 l/h.

MSMW155 is located to the far-west of the site immediately adjacent to the Crymlyn Bog; it is therefore likely that the gas concentrations observed at this location are associated with its proximity to the bog.

MSMW156 lies towards the south of the non-landfilled area. Available borehole logs indicate the presence of a significant thickness of Peat deposits and that hydrocarbon odour was noted. It is considered likely that the elevated gas concentrations may be due to degradation processes within the Peat and free-phase hydrocarbon contamination due to the refinery activities rather than migration from the landfilled waste mass.

#### 2.4.1.3. Non-landfill (east)

Two boreholes, CARW005 and CARW007, were monitored during April and May 2013. The concentration of both methane and carbon dioxide were negligible at both monitoring points with no exceedances of the threshold value. The gas concentrations were generally stable at the two monitoring points as shown in the graphs 8 and 9 in Appendix B.3.

#### 2.4.1.4. Off-site (east)

One borehole, CARW002, was monitored on 3 occasions during April and May 2013. Methane concentrations were detected at levels below the threshold trigger value. The carbon dioxide threshold was exceeded during two of the monitoring rounds as shown in Table 2–7.

**Table 2–7 Summary of carbon dioxide monitoring within off-site (east) area**

| Borehole | 09/04/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|
| CARW002 | 0.4 | 2.4 | 7.2 |

Concentrations measured as %v/v

‘borehole not monitored.

The driller’s log for this borehole records an observed hydrocarbon odour at the depth of the installation. It is likely that the gas detected is due to the historical hydrocarbons emanating from the tank farm. A steady increase in carbon dioxide concentration was observed over the monitoring period as shown in the graph 11 in Appendix B.4.

#### 2.4.1.5. Off-site (south)

Gas monitoring was carried out at two depths within borehole MSMW154. The methane concentrations in exceedance of the trigger value are highlighted in grey in Table 2 – 9 below.

**Table 2–8 Summary of methane monitoring within off-site (south) area**

| Borehole | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|
| MSMW154D | 0.4 | 8.2 | 4.8 | 3.3 | 49.6 | 0.2 | 0.2 |
| MSMW154S | 1.3 | 19.9 | 15.5 | 13.1 | 83.7 | 1.3 | 18.6 |

Concentrations measured as %v/v

‘borehole not monitored.

The highest methane concentration was detected at the shallow installation MSMW154S (gravel), where a concentration of 83.7%v/v was detected. Gas concentrations at the shallow depth were in excess of the trigger value on every monitoring round. The concentrations at both locations are shown to be highly variable over time as shown in the graph 12 in Appendix B.5, however both monitoring points showed similar trends in gas concentration, suggesting the same source of gas if affecting both points, likely to be the Crymlyn Bog or the former refinery adjacent to the monitoring location.

The carbon dioxide concentrations are summarised in Table 2–9.

**Table 2–9 Summary of carbon dioxide monitoring within off-site (south) area**

| off-site (south) | 28/11/2011 | 06/12/2011 | 15/12/2011 | 03/01/2012 | 12/02/2013 | 24/04/2013 | 08/05/2013 |
|---|---|---|---|---|---|---|---|
| MSMW154D | 0.3 | 2.7 | 1.8 | 1.3 | 5.7 | 0.3 | 0.3 |
| MSMW154S | 13.9 | 13.1 | 11.2 | 11.8 | 7.8 | 2.7 | 12.8 |

Concentrations measured as %v/v

‘borehole not monitored.

The results show that the concentration of carbon dioxide shows a similar variable pattern as the methane concentrations. The highest concentration was detected in MSMW154S, with a concentration of 13.9%v/v. In general lower concentrations of both methane and carbon dioxide were detected within the deeper installation. The elevated gas concentrations at this location are considered to be due to the influence of the nearby Crymlyn Bog and potentially its location adjacent to the former refinery south of the permitted area.

### 2.4.2. Sub-surface Migration and Vegetation Stress

Elevated landfill gas concentrations detected at the infilled section in the eastern half of the site are shown to be due to the deposited sludge waste. Away from this landfilled area, elevated concentrations of methane and carbon dioxide are most likely due to a historical spillage occurring from the refinery. There is also evidence that the presence of Peat deposits in the non-landfilled western section of the site could be responsible for the elevated gas concentrations. This is demonstrated by the similar trends observed in CARW015, CARW025 and MSMW156S2 (shown in graph 7 in Appendix B.2), which all contain shallow Peat deposits at the intake section of the monitoring installations. The source of the high gas concentrations emanating from the Peat deposits could be due to a historical hydrocarbon spillage from the southern tank farm that may have been attenuated within the shallow Peat deposits at these locations, with ground gases released from the degradation processes.

Elsewhere to the far west of the non-landfilled area, elevated gas concentrations are deemed as most likely due to the proximity of the site to the Crymlyn Bog. There is little evidence to suggest that gas migration from the waste mass is occurring or is responsible for elevated concentrations detected away from the landfilled area.

Vegetation stress has not been observed at the site. This has therefore not been considered during the assessment.

### 2.4.3. Atmospheric Dispersion and Odour

Since no modelling has been undertaken, Predicted Environmental Concentrations have not been determined, hence it is not possible to determine atmospheric dispersion and odour.

### 2.4.4. Exposure

Exposure doses to population has not been modelled.

### 2.4.5. Global Atmospheric Impact

The global atmospheric impact has not been modelled.

### 2.4.6. Landfill Gas Completion Criteria

Based on the data assessed, there is evidence to suggest that elevated gas concentrations within the eastern landfilled area is due to deposited sludge. To the west of the permitted area the detection of gas has been linked to the underlying Peat deposits and degradation of spilled hydrocarbons from the southern tank farm are thought to be responsible for the gas emissions. There is little evidence to suggest that nearby receptors are being affected by the migration of landfill gas from the waste mass. It is apparent from the Hydrogeological Risk Assessment (HRA) that away from the waste mass, that there is little evidence of the landfill having any impact on the environment and that Contaminants of Concern (COCs) are detected in higher concentrations away from the permitted area; particularly to the south. This appears in line with the gas concentrations detected across the site, with the highest found to the south of the site near the refinery. It is accepted that the assessment has been based on limited data.

# 3. Landfill Gas Management Plan

## 3.1. Control Measures

As described in Section 2.4 of the ESID Report, there are currently no active gas management measures in place at the landfill.

## 3.2. Monitoring and Sampling Plan

Given that all boreholes monitored displayed variable gas concentrations over the monitoring period, it is proposed that monitoring be carried out monthly for a continuous period of 12 months. The locations of the boreholes and the frequency of monitoring are summarised in Table 3–1 below and shown on Drawing ESID 8. The boreholes are to be monitored using a portable infra-red analyser for % methane by volume, % carbon dioxide by volume, % oxygen by volume and atmospheric pressure.

**Table 3–1 Proposed monitoring plan**

| Location | Boreholes | Monitoring Frequency |
|---|---|---|
| In-landfill | CBH2, CBH20, CBH31, CBH33, CBH36, CBH37, CBH41, CBH42, CBH48, CBH58, CBH63, MSMW228, MSMW235, MSMW236, MSMW238, MSMW239, MSMW033D, MSMW035S and CARW024. | Monthly |
| Non-landfill (west) | CARW015, CARW025, CAR029B, GA7S, MSMW156S1, MSMW156S2, MSMW156D, MSMW027S, MSMW155S and MSMW155D. | Monthly |
| Non-landfill (east) | CARW005. | Monthly |
| Off-site (east) | CARW002. | Monthly |
| Off-site (south) | MSMW154S and MSMW154D. | Monthly |

Weather conditions to be recorded at start and end of monitoring including rainfall, cloud cover, atmospheric pressure and change (rising, falling or staying constant), wind speed and direction, atmospheric humidity, and temperature as per Environment Agency Guidance requirements.

Data obtained from the monitoring will be stored in a database. This data will be reviewed against Control and Trigger levels noted in Section 1.2.4 and an evaluation of risk made on this basis.

Results will be reported to the Environment Agency on an annual basis in an agreed format and presentation, or in the event of abnormal operations results will be reported as per the Action Plan detailed in Section 3.3.

# 4. Conclusions

## 4.1. Compliance with the Landfill Directive 1999

The assessment of risk posed by the generation of landfill gas within Crymlyn Tip landfill completed within this report has shown that the landfilled area in the east of the site is producing landfill gas. The source of the landfill gas is likely to be from the degradation of placed hydrocarbon sludge waste. West of this area in the non-landfilled zone, several monitoring points installed within the shallow Peat deposits exhibited similar patterns of behaviour of elevated gas concentrations. It is suggested that the gas detected at these monitored points are ground gases linked to the attenuation and degradation of hydrocarbons, associated with a historical oil spillage from the southern tank farm, within the underlying Peat deposits as well as degradation of the peat itself. The close proximity of the Crymlyn Bog may also be a factor. Based on this the site must be considered as compliant, as is little evidence of landfill gas migration occurring. However, given the high degree of variability in concentrations of gas across the site and the absence of monitoring data available, it is considered that there is need for further monitoring, ideally over a 12 month period.

# 5. References

Environment Agency. (2004). *Guidance on the management of landfill gas.* Bristol: The Environment Agency.

# Appendices

# Appendix A. Environment Agency Qualitative Risk Screening Tables

ENVIRONMENT AGENCY

RISK SCREENING TABLES

**Table 5–1 Environment Agency likelihood categories**

| | Category | Range |
|---|---|---|
| 1 | Extremely unlikely | Incident occurs less than once in a million years |
| 2 | Very unlikely | Incident occurs between once per million and once every 10,000 years |
| 3 | Unlikely | Incident occurs between once per 10,000 years and once every 100 years |
| 4 | Somewhat unlikely | Incident occurs between once per 100 years and once every 10 years |
| 5 | Fairly probable | Incident occurs between once per 10 years and once per year |
| 6 | Probable | Incident occurs at least once per year |

**Table 5–2 Environment Agency severity categories**

| | Category | Definition |
|---|---|---|
| 1 | Minor | Nuisance on site only – no outside complaint |
| 2 | Noticeable | Noticeable nuisance off-site, minor breach of permitted emission limits |
| 3 | Significant | Severe and sustained nuisance, major breach of permitted emissions limits with potential for prosecution |
| 4 | Severe | Hospital treatment required, public warning and off-site emergency plan invoked. |
| 5 | Major | Evacuation of local populace, temporary disabling and hospitalisation, serious toxic effect on beneficial or protected species. |
| 6 | Catastrophic | Major airborne release with serious offsite effects |

**Table 5–3 Severity likelihood matrix**

| Likelihood | Severity likelihood matrix | | | | | |
|---|---|---|---|---|---|---|
| | minor | noticeable | significant | severe | major | catastrophic |

| | | | | | | |
|---|---|---|---|---|---|---|
| Extremely unlikely | 1 | 2 | 3 | 4 | 5 | 6 |
| Very unlikely | 2 | 4 | 6 | 8 | 10 | 12 |
| Unlikely | 3 | 6 | 9 | 12 | 15 | 18 |
| Somewhat unlikely | 4 | 8 | 12 | 16 | 20 | 24 |
| Fairly probable | 5 | 10 | 15 | 15 | 25 | 30 |
| Probable | 6 | 12 | 18 | 18 | 30 | 36 |

**Table 5–4 Risk evaluation**

| Magnitude of risk | Score |
|---|---|
| Insignificant | 6 or less |
| Acceptable | 8 to 12 |
| Unacceptable | 15 or more |

# Appendix B. Gas Emissions Graphs

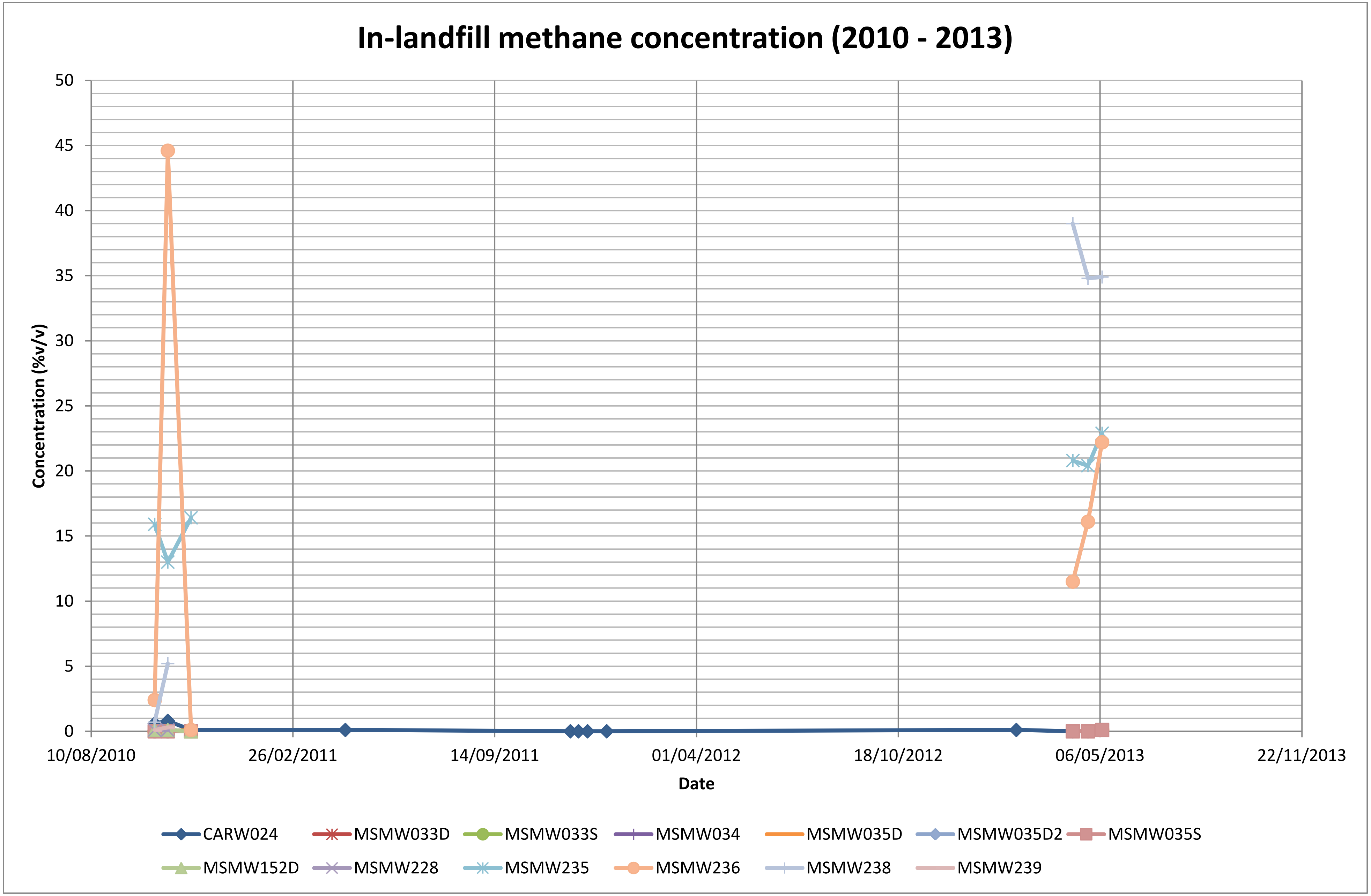
## B.1. In-landfill

## B.2. Non-landfill (west)

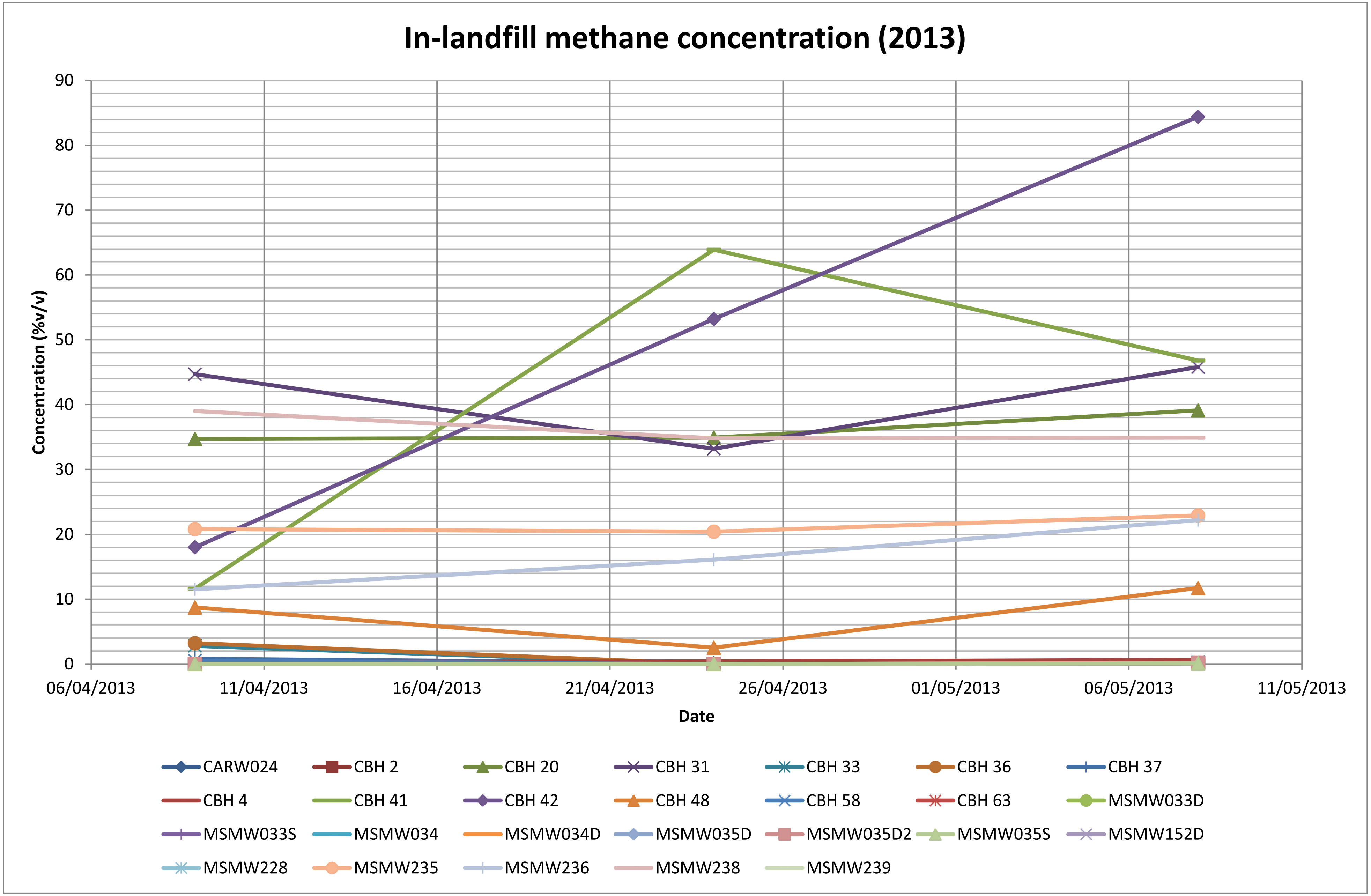
## B.3. Non-landfill (east)

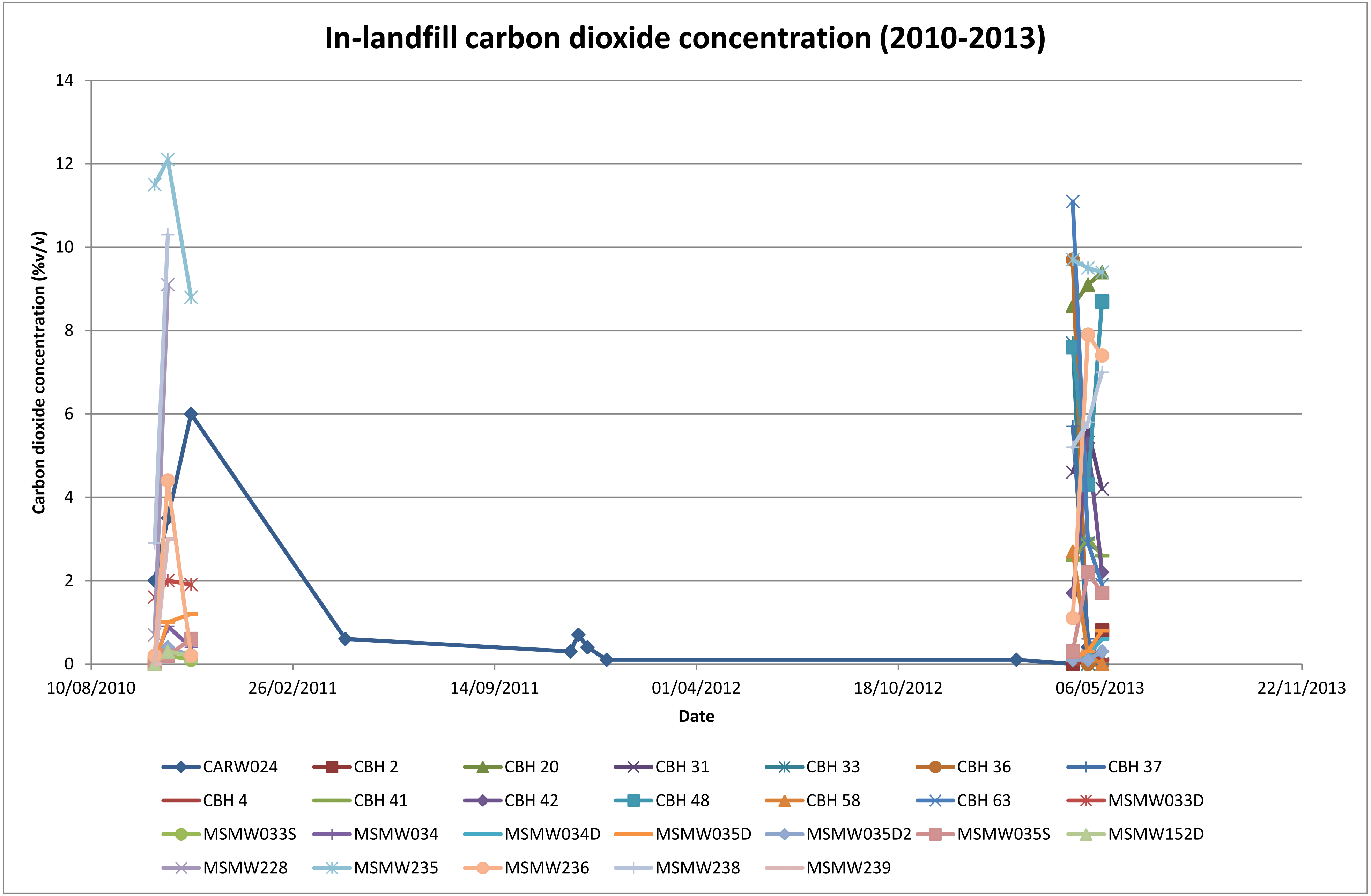
## B.4. Off-site (east)

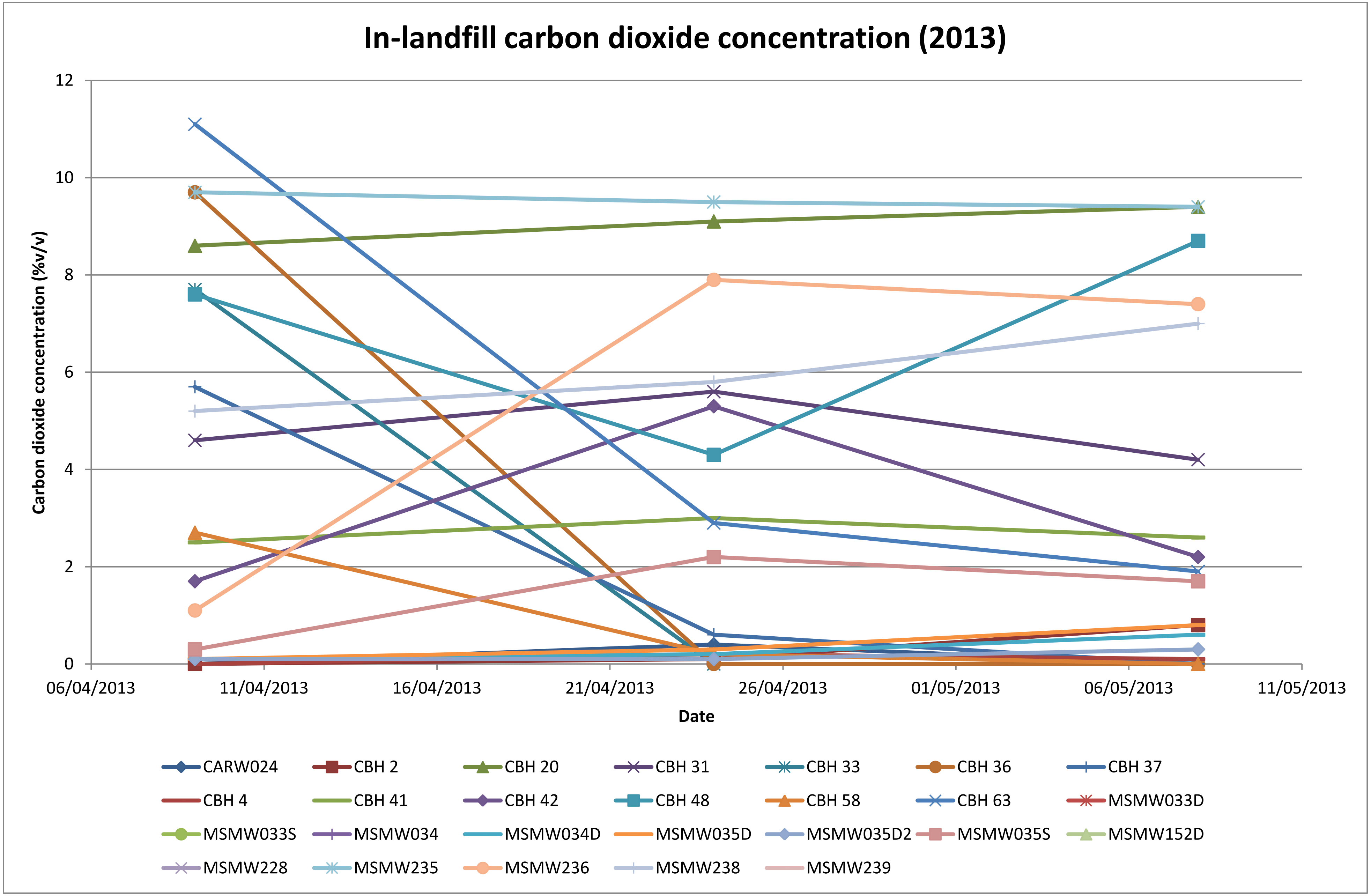
## B.5. Off-site (south)



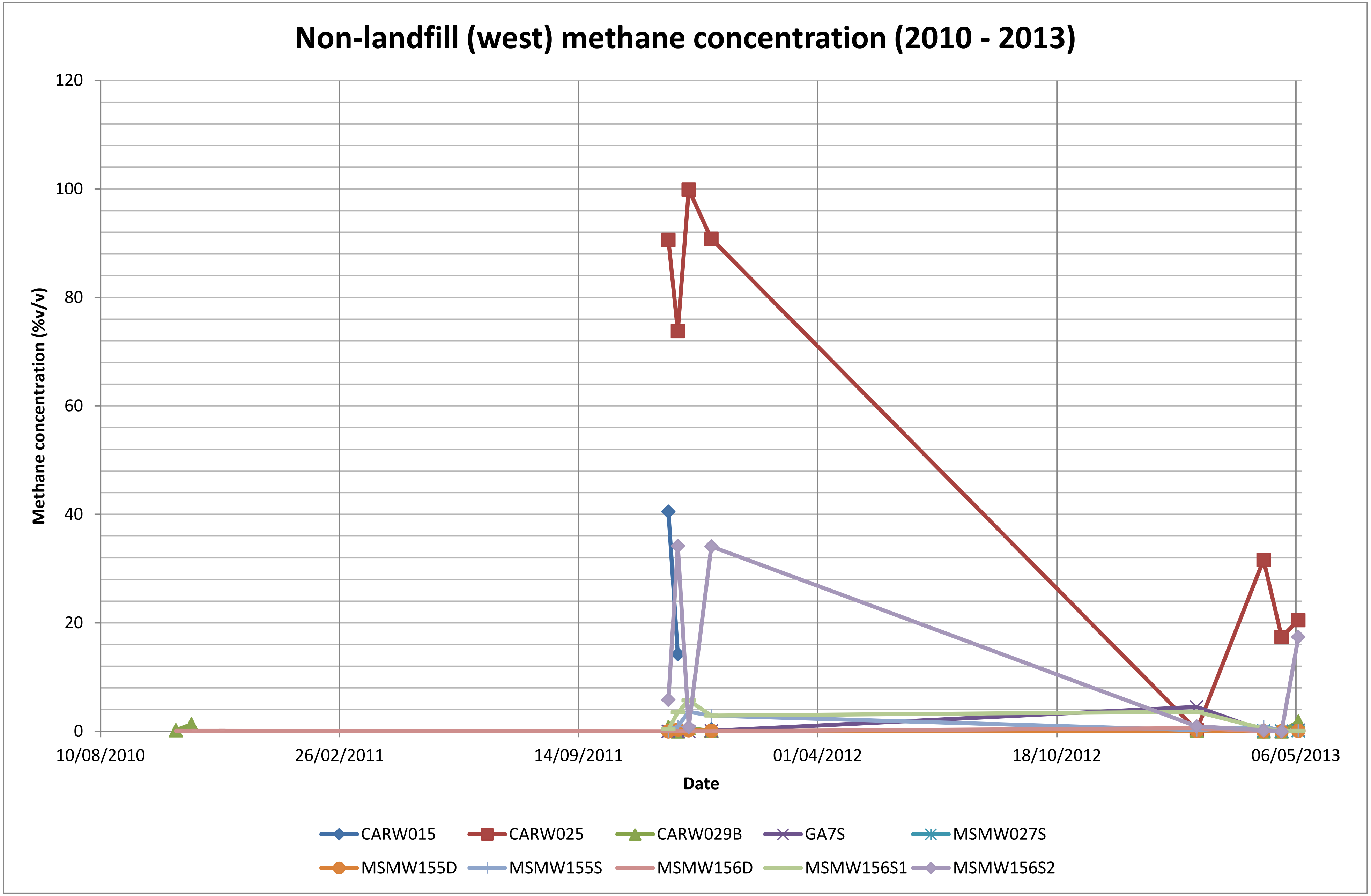
In-landfill methane concentration (2010 - 2013)
Concentration (%v/v)
50
45
40
35
30
25
20
15
10
5
0
10/08/2010
26/02/2011
14/09/2011
01/04/2012
18/10/2012
06/05/2013
22/11/2013
Date
CARW024
MSMW033D
MSMW033S
MSMW034
MSMW035D
MSMW035D2
MSMW035S
MSMW152D
MSMW228
MSMW235
MSMW236
MSMW238
MSMW239


In-landfill methane concentration (2013)
Concentration (%v/v)
Date
0
10
20
30
40
50
60
70
80
90
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
CARW024
CBH 2
CBH 20
CBH 31
CBH 33
CBH 36
CBH 37
CBH 4
CBH 41
CBH 42
CBH 48
CBH 58
CBH 63
MSMW033D
MSMW033S
MSMW034
MSMW034D
MSMW035D
MSMW035D2
MSMW035S
MSMW152D
MSMW228
MSMW235
MSMW236
MSMW238
MSMW239

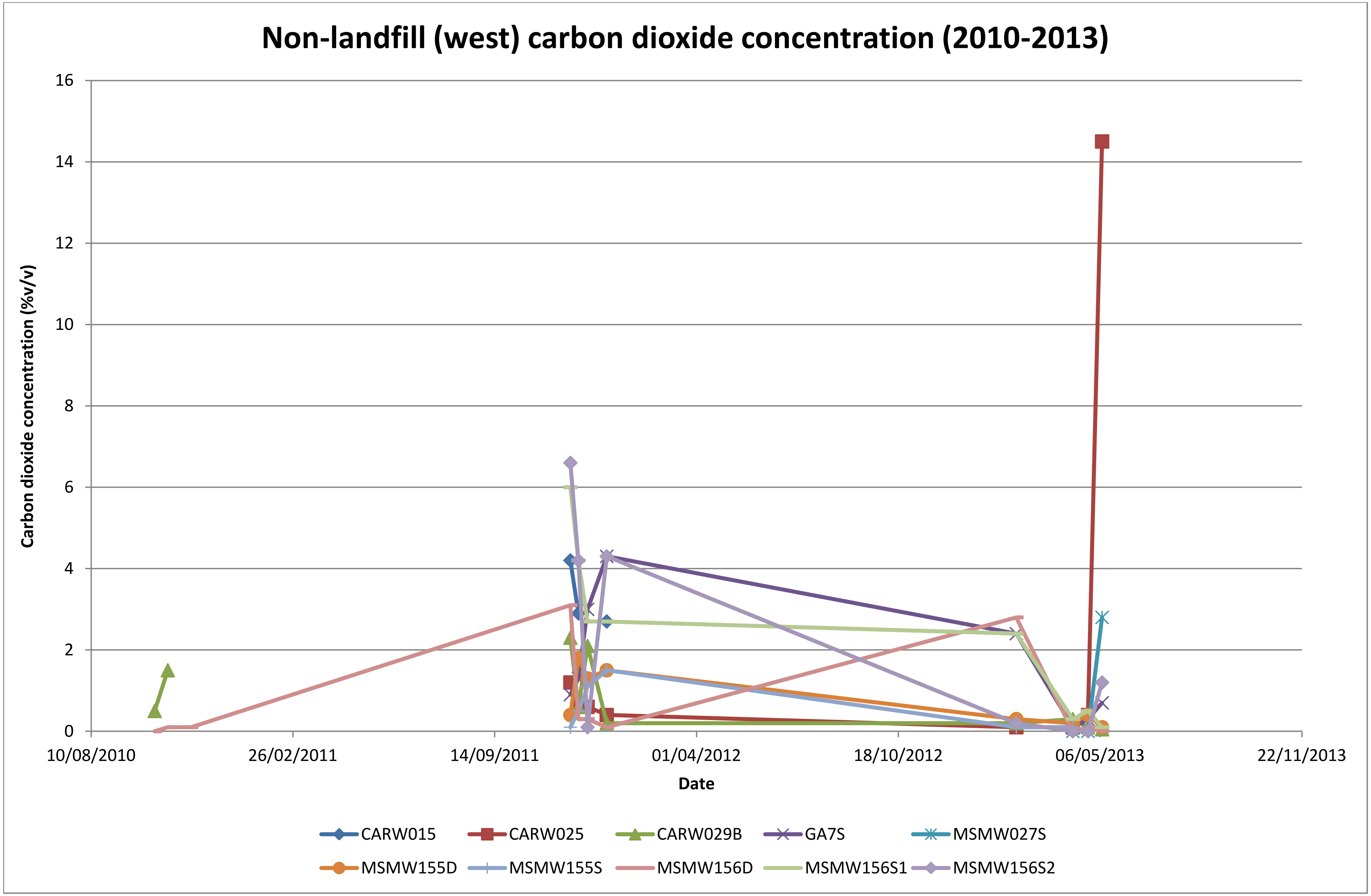

In-landfill carbon dioxide concentration (2010-2013)
14
12
10
8
6
4
2
0
Carbon dioxide concentration (%v/v)
10/08/2010
26/02/2011
14/09/2011
01/04/2012
18/10/2012
06/05/2013
22/11/2013
Date
CARW024
CBH 2
CBH 20
CBH 31
CBH 33
CBH 36
CBH 37
CBH 4
CBH 41
CBH 42
CBH 48
CBH 58
CBH 63
MSMW033D
MSMW033S
MSMW034
MSMW034D
MSMW035D
MSMW035D2
MSMW035S
MSMW152D
MSMW228
MSMW235
MSMW236
MSMW238
MSMW239

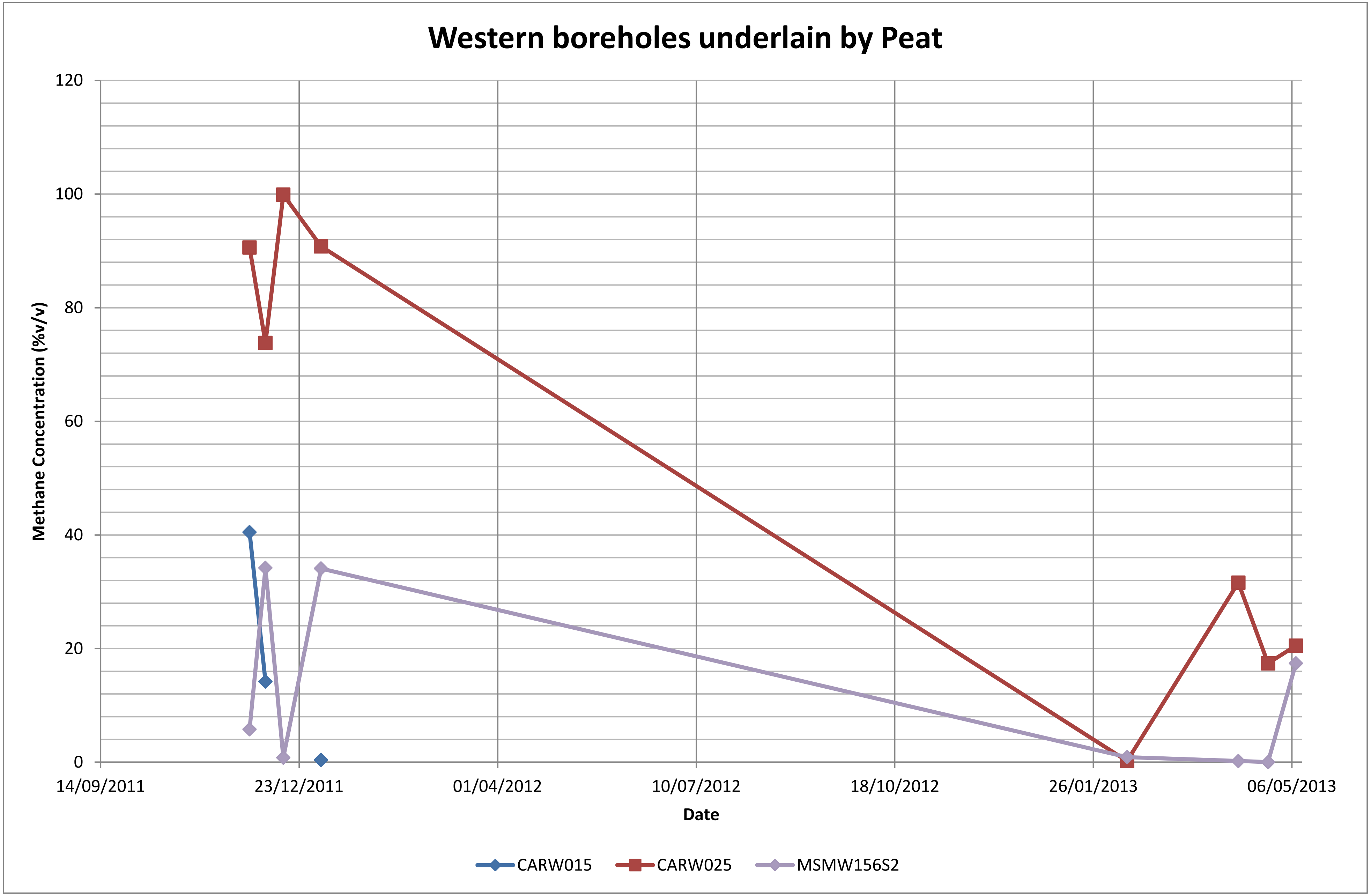


In-landfill carbon dioxide concentration (2013)
Carbon dioxide concentration (%v/v)
12
10
8
6
4
2
0
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
Date
CARW024
CBH 2
CBH 20
CBH 31
CBH 33
CBH 36
CBH 37
CBH 4
CBH 41
CBH 42
CBH 48
CBH 58
CBH 63
MSMW033D
MSMW033S
MSMW034
MSMW034D
MSMW035D
MSMW035D2
MSMW035S
MSMW152D
MSMW228
MSMW235
MSMW236
MSMW238
MSMW239

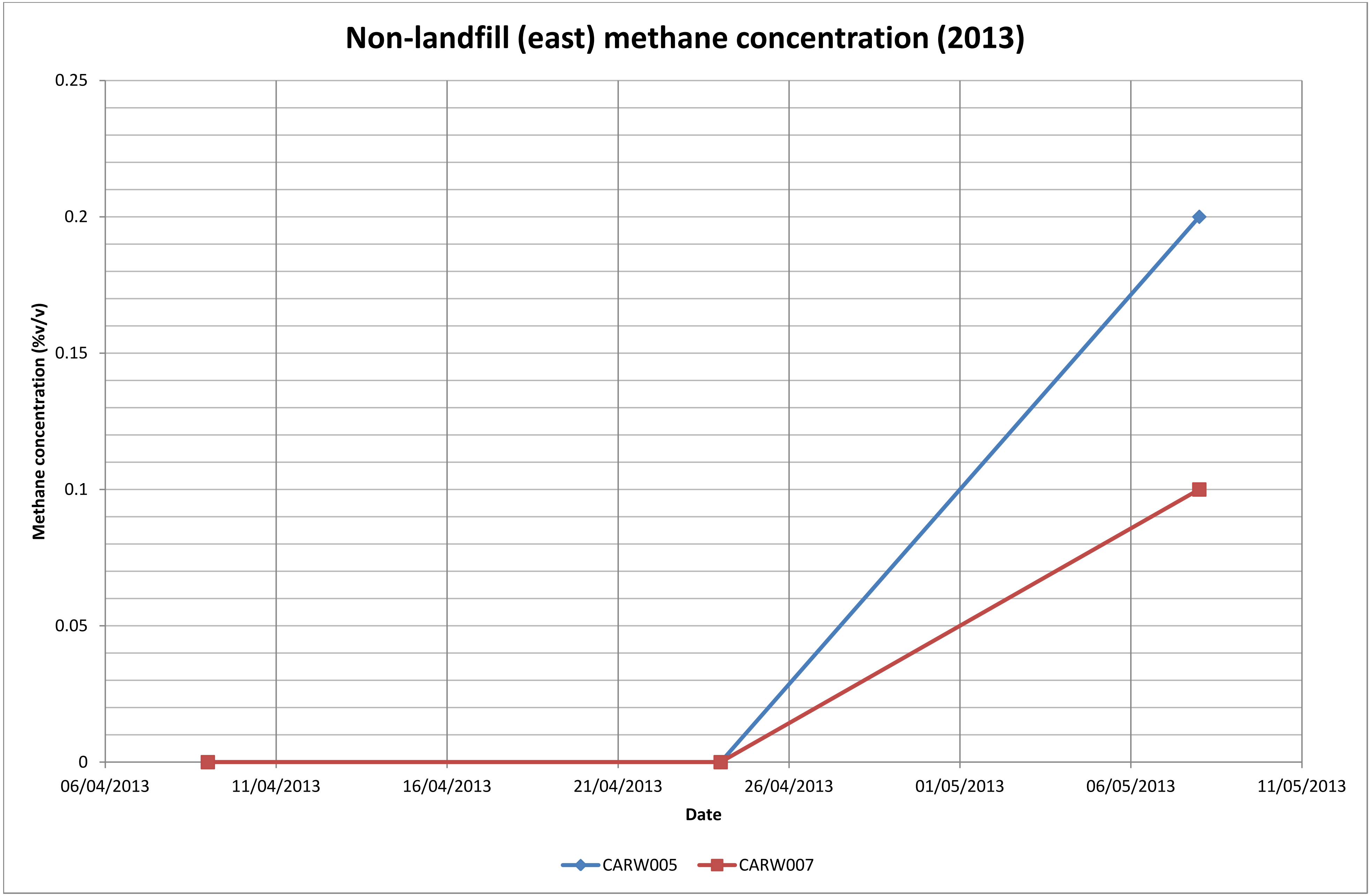


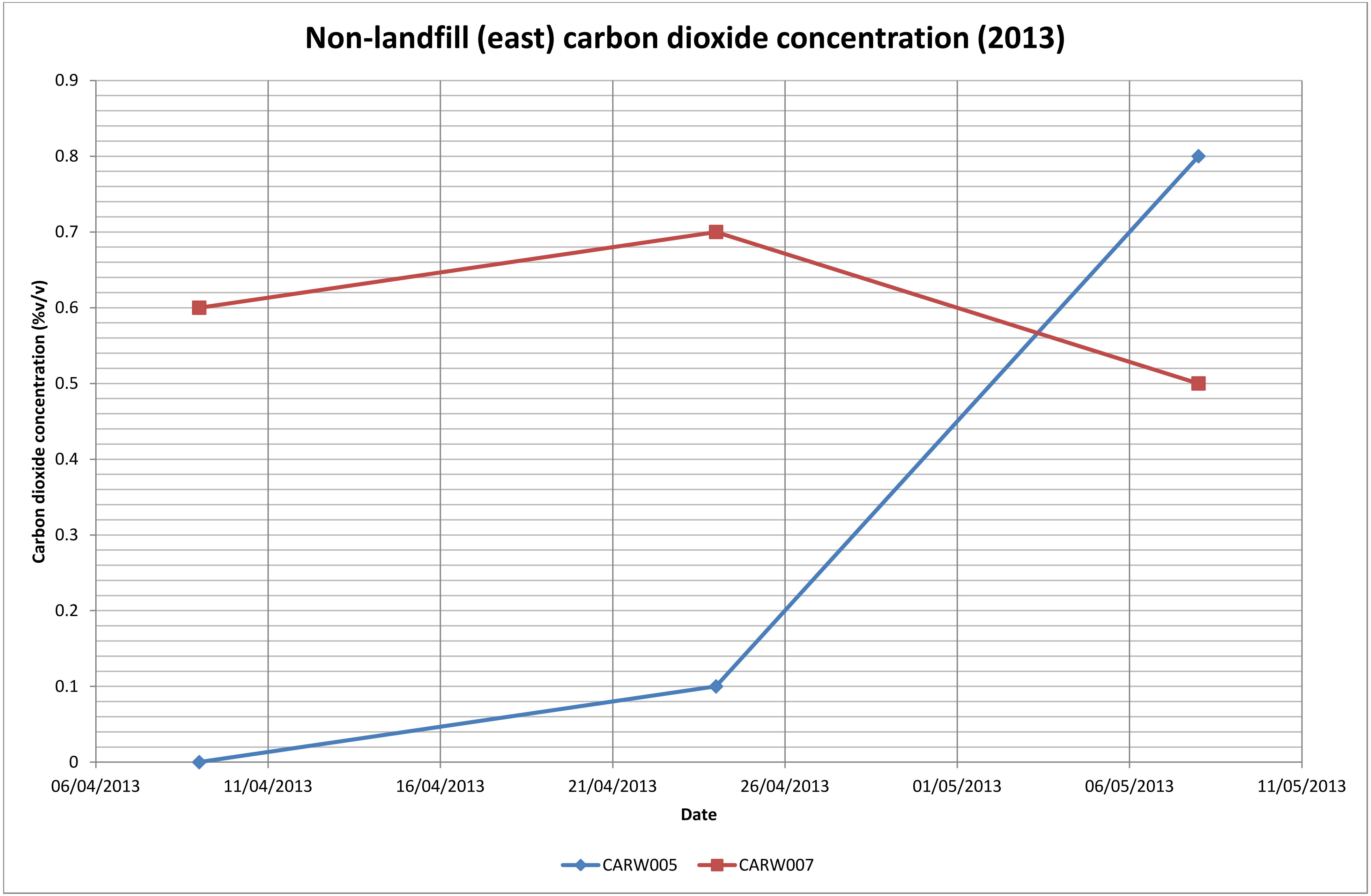
Non-landfill (west) methane concentration (2010 - 2013)
Methane concentration (%v/v)
120
100
80
60
40
20
0
10/08/2010
26/02/2011
14/09/2011
01/04/2012
18/10/2012
06/05/2013
Date
CARW015
CARW025
CARW029B
GA7S
MSMW027S
MSMW155D
MSMW155S
MSMW156D
MSMW156S1
MSMW156S2


Non-landfill (west) carbon dioxide concentration (2010-2013)
Carbon dioxide concentration (%v/v)
16
14
12
10
8
6
4
2
0
10/08/2010
26/02/2011
14/09/2011
01/04/2012
18/10/2012
06/05/2013
22/11/2013
Date
CARW015
CARW025
CARW029B
GA7S
MSMW027S
MSMW155D
MSMW155S
MSMW156D
MSMW156S1
MSMW156S2

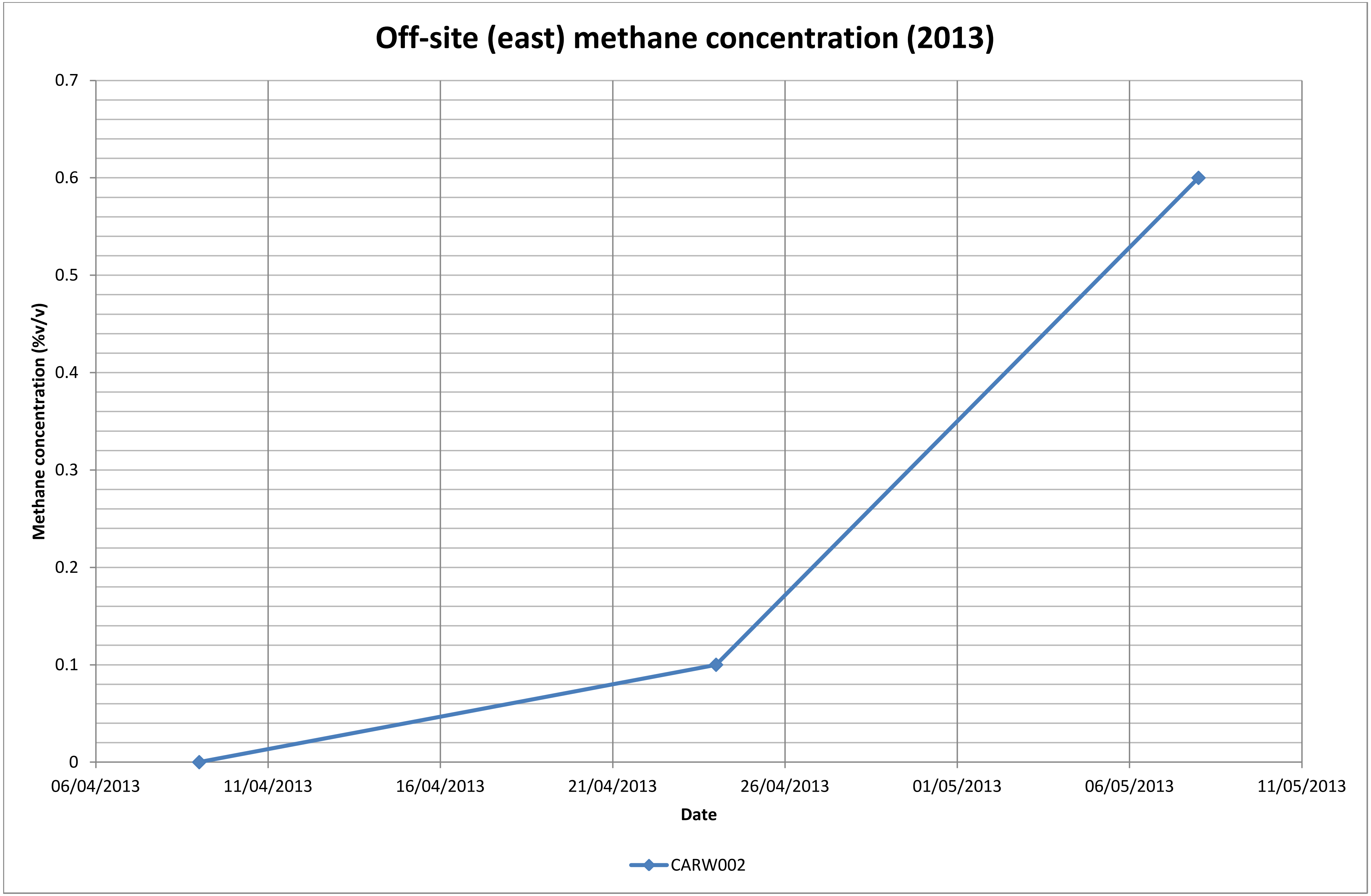


Western boreholes underlain by Peat
Methane Concentration (%v/v)
120
100
80
60
40
20
0
14/09/2011
23/12/2011
01/04/2012
10/07/2012
18/10/2012
26/01/2013
06/05/2013
Date
CARW015
CARW025
MSMW156S2

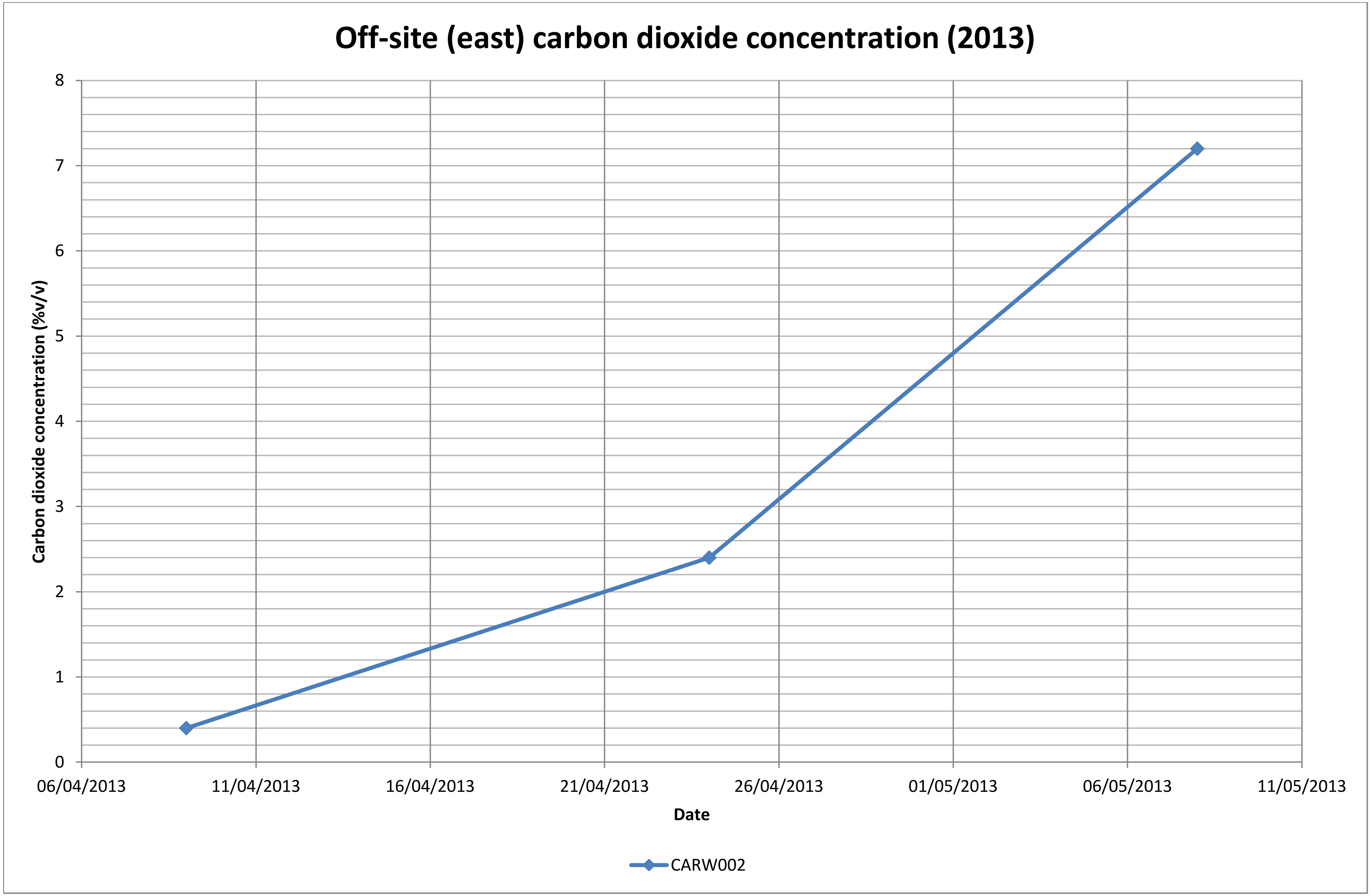

Non-landfill (east) methane concentration (2013)
Methane concentration (%v/v)
0.25
0.2
0.15
0.1
0.05
0
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
Date
CARW005
CARW007



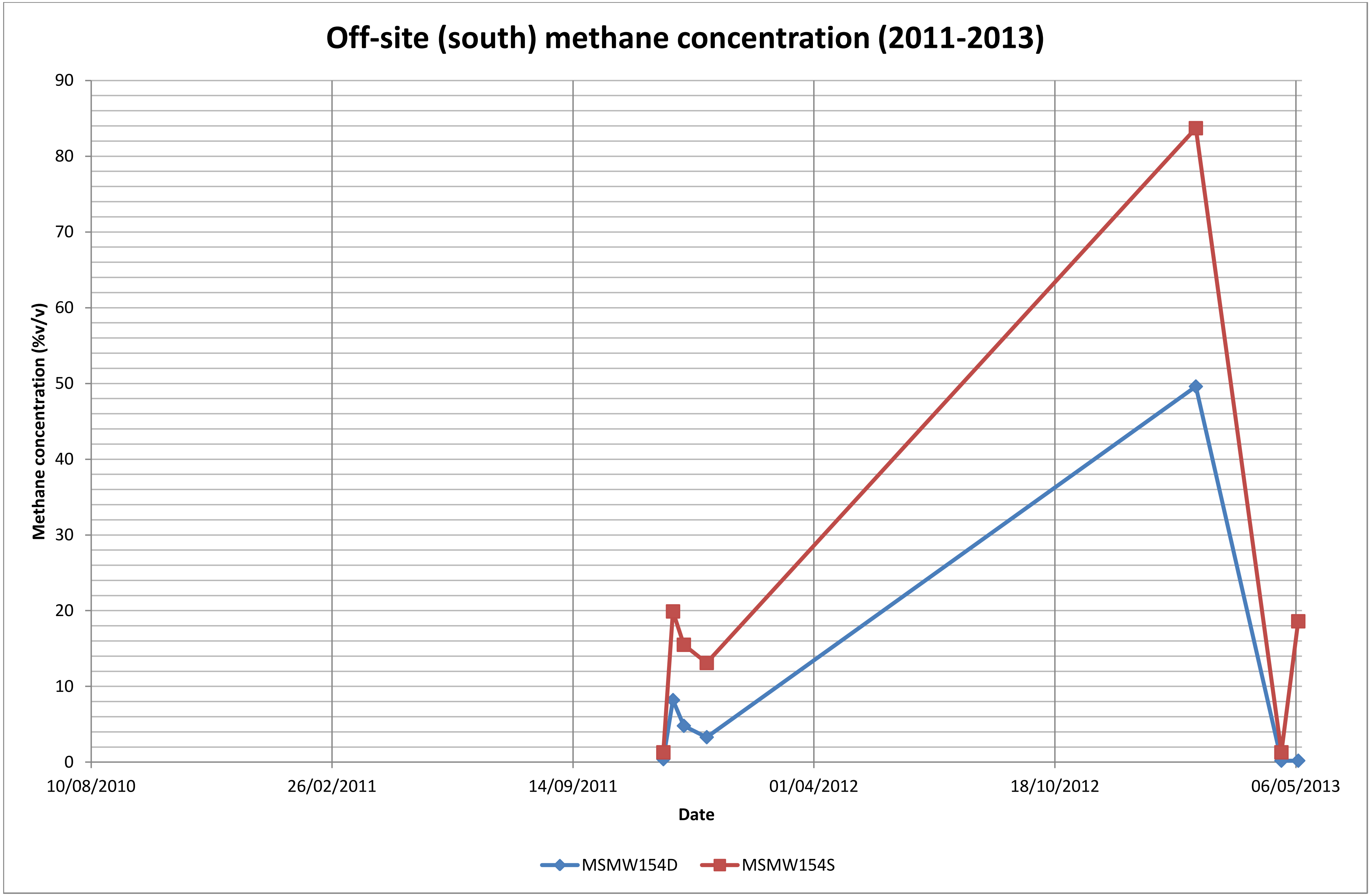
Non-landfill (east) carbon dioxide concentration (2013)
Carbon dioxide concentration (%v/v)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
Date
CARW005
CARW007



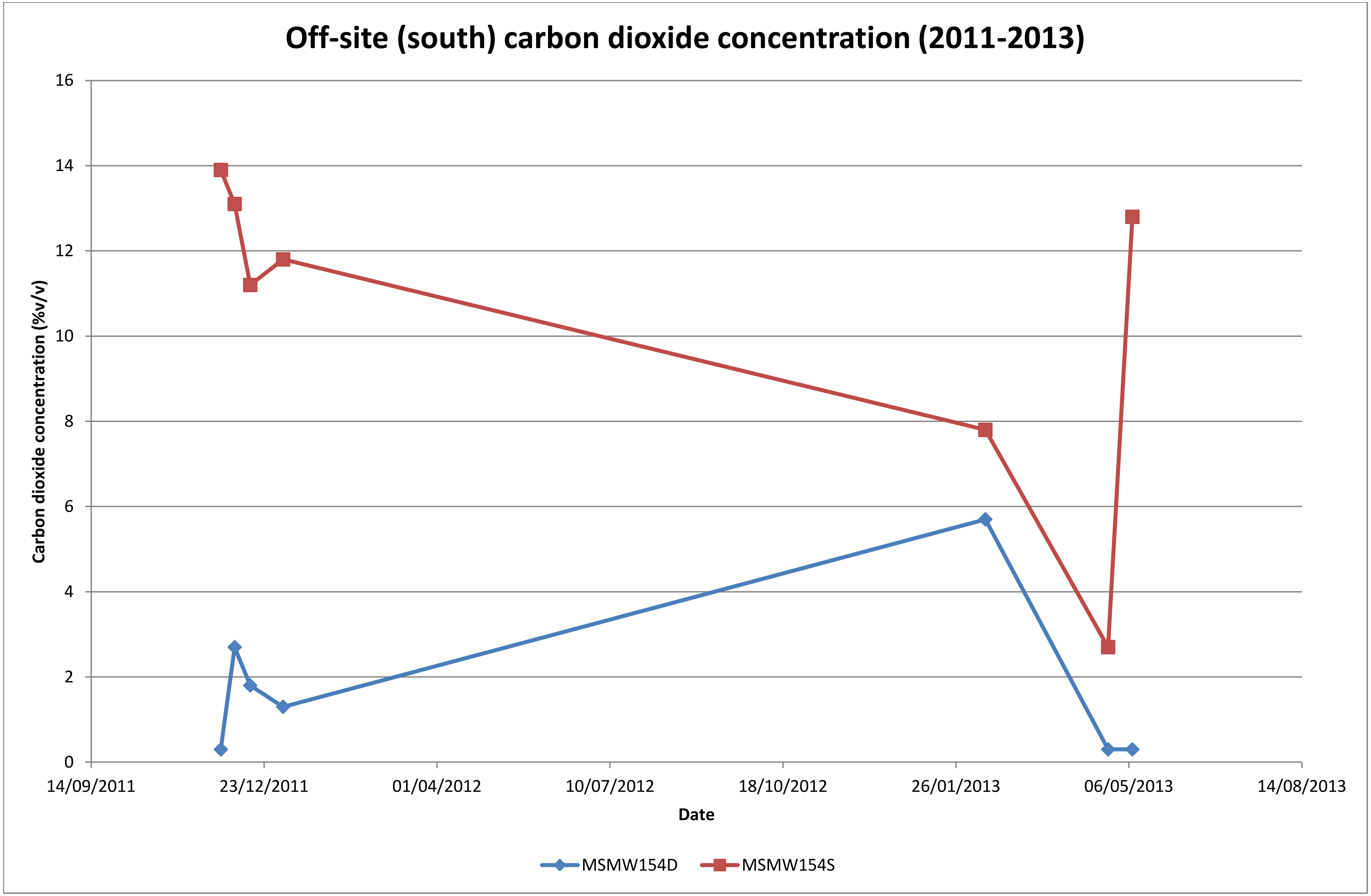
Off-site (east) methane concentration (2013)
Methane concentration (%v/v)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
Date
CARW002



Off-site (east) carbon dioxide concentration (2013)
Carbon dioxide concentration (%v/v)
0
1
2
3
4
5
6
7
8
06/04/2013
11/04/2013
16/04/2013
21/04/2013
26/04/2013
01/05/2013
06/05/2013
11/05/2013
Date
CARW002



Off-site (south) methane concentration (2011-2013)
Methane concentration (%v/v)
0
10
20
30
40
50
60
70
80
90
10/08/2010
26/02/2011
14/09/2011
01/04/2012
18/10/2012
06/05/2013
Date
MSMW154D
MSMW154S



Off-site (south) carbon dioxide concentration (2011-2013)
Carbon dioxide concentration (%v/v)
16
14
12
10
8
6
4
2
0
14/09/2011
23/12/2011
01/04/2012
10/07/2012
18/10/2012
26/01/2013
06/05/2013
14/08/2013
Date
MSMW154D
MSMW154S

**Richard Mitchener**
Atkins
The Axis
10 Holliday Street
Birmingham
B1 1TF

**richard.mitchener@atkinsglobal.com**