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30 June 2013

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Dear Gary

REVIEW OF PETROLEUM WASTE LAND FARMING

1.0 Summary

This review, for the Taranaki Regional Council, examines consent conditions and monitoring results for several Taranaki Region landfarming sites being used to bioremediate hydrocarbon-containing wastes from the oil exploration and production industry. The broad intent of the review was to determine whether landfarming is an environmentally viable thing to do and, if so, whether the process is being managed appropriately by the Council. The review is not an audit of specific landfarming operations, nor an audit of Council's actions with respect to specific landfarms.

In summary, landfarming is a valid and environmentally acceptable means of waste treatment with appropriate controls. There is no reason why such landfarming should not continue, subject to controls being imposed by means of consent conditions appropriate to each site and the waste being handled. It should be noted that most landfarmed wastes in Taranaki have relatively low hydrocarbon concentrations and low heavy metal concentrations.

In general, the intent and nature of the controls imposed by the Council are appropriate. These controls, based on international best practice, have evolved as experience has been gained with Taranaki conditions. As a result, the Council has revised and improved the earlier resource consent conditions, particularly around groundwater monitoring and lining of waste storage pits, in more recent consents. All active landfarms now have groundwater monitoring in place and lined storage pits. In addition, the Council is actively pursuing research into whether there are low-level toxic effects on soil organisms from landfarmed wastes. Interim results suggest little if any effects on soil organisms.

It is recommended the Council review the allowable initial hydrocarbon concentrations, so that the intent of a maximum average concentration of 20,000 mg/kg in soil is achieved. In addition, the Council should review the applicability of the current human-health-based hydrocarbon limits at the time of consent expiry, rather than ecologically-based limits. It is understood the Council is currently seeking expert advice on this issue.

It is also recommended that, combined with a review of the applicability of the recently implemented National Environmental Standard for the Assessing and Managing of Contaminants in Soil to Protect Human Health (the NES) to former landfarming sites, the Council consider the applicability of the new soil contaminants standards for arsenic and lead, rather than using biosolids guidelines for these heavy metals. If the NES is applicable, landfarming sites should be listed on the Council's Selected Land Use Register, and the appropriate territorial authority advised.

The Council should update the regional guidelines and continue updating consent conditions as best practice evolves. However, within the limited extent that particular consent and compliance reports were sighted during this review, no evidence was seen suggesting significant adverse effects have occurred from past or current landfarming activities in compliance with their consents.

2.0 Introduction

The Taranaki Regional Council (TRC) has engaged Dr Graeme Proffitt of Pattle Delamore Partners Limited (PDP) to review the practice of land farming of the solid and semi-solid wastes from the hydrocarbon exploration and production industry in the Taranaki Region. The specific questions asked to be address as part of this review are:

1. Is the concept of using natural biodegradation a feasible and valid way of managing hydrocarbon-bearing wastes?
2. Are the various guidelines and standards that the TRC references/incorporates in its consent conditions appropriate for a treatment system that relies on natural degradation of hydrocarbon-containing wastes – so that degradation can in fact occur, and so that it is not overwhelmed by excessive concentrations that might be toxic to the natural processes?
3. Are the various guidelines and standards that the TRC references/incorporates in its consent conditions appropriate for providing offsite environmental protection during the time degradation is occurring?
4. Are the guidelines as applied in the consents appropriate for protecting potential subsequent use that might incorporate pastoral usage?
5. Is the nature, scale and scope of the monitoring (taking the Council and consent holder's requirements together) a scientifically and technically sound programme, that can be considered to offer reasonable certainty about the environmental state of each area?
6. Does the Council accurately and fairly report the implications of the results of monitoring, in terms of both consent compliance and of environmental effects?
7. Based on either what you generally know of the behaviour of hydrocarbons in soil, or on what you find in your review of the consents and reports that the Council is providing, is there any sound and evidence–based reason why the practice of land-farming should or should not be allowed to continue in Taranaki?
8. Is there any other matter that you consider the Council should be made aware of, in relation to the matter of consenting and monitoring the land application and treatment of hydrocarbon-bearing waste in the region?

3.0 Approach to Review

This review was a desktop exercise, largely relying on documents provided by TRC, and discussions with Mr Gary Bedford of TRC. No landfarming sites were visited. A list of the documents provided is attached as Appendix A.

The documents, along with consulting relevant literature (listed as references), were used to gain an overview of the landfarming practices within the region, and to assess whether these practices would achieve the intended objectives of waste disposal, result in land that was productive at the end of the process and not adversely affecting the wider environment.

It should be noted that this review is not an audit of the compliance of various land farming operations with the conditions of the applicable resource consents. Nor is it an audit of TRC's monitoring of these resource consents. However, if in reading the various documents, a possible non-compliance of a particular consent was apparent, this has been communicated separately to the Council.

4.0 Background

In the context of this review, landfarming is the process of spreading drilling waste onto land, incorporating the waste into the soil, and then re-sowing the area in pasture or crop to allow natural bioremediation to occur as various soil processes biodegrade, transform and assimilate the waste.

Typical steps used for the landfarming of drilling wastes are:

1. Transporting the waste from well sites by truck (cuttings) or tanker (liquids) to the landfarming site where it may be discharged directly to land or placed in a storage pit.
2. Preparing the landfarming area by scraping back and stockpiling existing pasture/topsoil and levelling uneven ground.
3. Transferring the waste (possibly after blending with other waste to reduce contaminant concentrations) to the prepared area by excavator and truck and spreading with a bulldozer. Liquids may be discharged by tanker or a spray system.
4. After allowing the waste to dry sufficiently, incorporating the waste into the soil, typically to a depth of 250 mm, by tilling the soil with rotary harrows.
5. Re-spreading stockpiled topsoil or spreading imported soil to aid stability of the soil surface and assist in pasture establishment.
6. Re-establishing vegetation, whether pasture or crop, at a suitable time of year. Fertiliser may be applied at this time.

Many of the landfarms in Taranaki have been on poorer, sandy, coastal soils which generally are not capable of sustaining good pasture and are prone to erosion. The intention is that the waste will improve the texture of the receiving soil and make it less erosion prone. The well-drained nature of these soils possibly allows waste application to be carried out over longer periods of the year than in heavier soils where high soil moisture over wetter periods would make runoff more likely and prevent working of the soil. However, leaching to groundwater is more likely in well-drained soils. Landfarming is not just restricted to coastal soils, but is also being carried out on heavier, volcanic-ash derived silty and clayey soils.

Drilling wastes generally consist of:

- rock cuttings removed by drilling through geological formations;
- drilling fluids (drilling mud) adhering to cuttings;
- unwanted or non-recyclable drilling fluids; and
- oily wastes such as oily formation sand, sludges and slops removed from tanks and separators, and soil from drill sites contaminated with leaks and spills.

Drilling fluids have multiple roles, such as cooling and lubricating the drill-bit, lifting cuttings to the surface, counteracting the formation pressure and preventing hole collapse, preventing excessive loss of fluid into the formation and lubricating the drill string. Drilling fluids or muds may be water-based (WBM), synthetic-based (SBM) or, as in the past, oil-based (OBM) mud systems (generally now not used in Taranaki). Water-based muds have fresh or salt water as the primary fluid, oil-based muds use diesel, kerosene, refined mineral oils or crude oil as an emulsion within water or water emulsified within the oil, while synthetic-based muds use various synthetic oil-like fluids as the primary fluids. The different types of muds may use natural bentonite clay or other clays, synthetic polymers and natural gums as viscosifying agents.

Oil-based muds have a variety of advantages over water-based muds including better dealing with more difficult geological conditions, better lubrication of the drill string and greater penetration rates, with the major disadvantage being that they are more toxic and less environmentally friendly than water-based muds, and therefore more difficult to

dispose of. In particular, oil-based mud wastes have much higher hydrocarbon concentrations than water-based or synthetic muds, including the mono-aromatic BTEX compounds (benzene, toluene, ethyl benzene and toluene). Synthetic-based muds were developed to have the advantages of oil-based muds while being much more environmentally friendly, and have generally replaced oil-based muds.

Drilling fluids contain a variety of substances other than viscosifiers to produce desirable properties for the particular drilling situation. These may include weighting agents such as barite (barium sulphate) and calcite (calcium carbonate), pH control additives such as lime and sodium hydroxide, various inorganic salts, emulsifiers, corrosion inhibitors, various materials to prevent loss of fluid into the formation, lubricants, bactericides and defoamers.

Drilling mud is expensive and is constantly modified, cleaned and recycled during drilling. A variety of "solids control" equipment is used to treat the mud to remove drill cuttings, maximise fluid recovery and minimise volumes of waste for disposal. Water-based and synthetic-based muds, and therefore wastes from these muds, may become contaminated with hydrocarbons during the drilling process. Other common contaminants are various inorganic salts, particularly sodium chloride (common salt) and various heavy metals from the rock drilled through. In general, heavy metal concentrations in Taranaki region drilling wastes are low; a reflection of the regional geology.

Currently there are eight sites actively being used for landfarming drilling wastes, or ready to begin taking wastes, in the Taranaki Region. Six of the sites are in coastal locations while two are inland sites near Inglewood. A further four sites are no longer taking wastes but still hold resource consents and are still being monitored.

All sites are required to have resource consents to discharge contaminants to land. These consents have a variety of consent conditions, some common across sites and some tailored to the particular site, intended to control the environmental effects of the activities. Included are controls on contaminant concentrations, contaminant loading rates and effects on water. Sampling of soil and water is required of the consent holder to monitor contaminant inputs and the effects and progress of the landfarming. The Council also carries out regular compliance monitoring, which is documented in annual reports for each site. The reports are publicly available on the Council's website.

The Council has produced guidelines (TRC, 2005) for the disposal of drilling wastes, based on Canadian guidelines but modified for the Taranaki environment. The Taranaki soil and climate conditions are perceived as being rather more conducive to bioremediation than Canadian conditions, where soil may be frozen through the winter months.

The Council guidelines include recommended consent conditions. These have been reviewed from time to time, based on experience gained from more than a decade of monitoring landfarming operations, to produce updated standard landfarming consent conditions. This means that older consents tend to have conditions that closely match the recommendations in TRC (2005) while more recent consents have some departures (generally more stringent) from the original recommendations.

5.0 Review

This section discussed each of the questions posed by TRC as separate sub-sections. The sub-sections have the same numbering as the questions.

As a general comment, it is apparent that the controls exercised by TRC, through imposition of consent conditions, have changed over the years, generally becoming more stringent or explicit. This has resulted from a combination of experienced gained, changes in guideline documents and a conscious review as to the appropriateness of various controls. This is to be commended and should continue.

Given that some consents are now less stringent than some other more recent consents of a similar nature, it is recommended that the Council review the older but still active landfarming consents as the opportunity arises (i.e. as review dates in the consent fall due, if review is not possible otherwise) and, as appropriate, impose conditions consistent with the more recent consents.

5.1 Feasibility and validity

Question 1: *Is the concept of using natural biodegradation a feasible and valid way of managing hydrocarbon-bearing wastes?*

This question has two parts; feasibility and validity. In turn the first part, feasibility has both technical and economic components. Economics is beyond the scope of this review, but from a technical point of view, natural biodegradation through landfarming is an entirely feasible means of managing hydrocarbon-bearing wastes, provided the various contaminants in the waste do not overload or inhibit the ability of the microbial communities in the soil to degrade the hydrocarbons.

Validity is largely a matter of policy. In so far as the Resource Management Act 1991 (RMA) allows discharges of contaminants into the environment when permitted by a rule in a plan or by a resource consent, then landfarming of hydrocarbon waste is valid. The TRC has chosen as a matter of policy to require resource consents for landfarming of hydrocarbon-bearing waste. The issue is then whether the conditions of the resource consent are such as to be sufficiently protective of the environment. Answers to the subsequent questions examine the detail of this issue.

5.2 Input guidelines and standards

Question 2: *Are the various guidelines and standards that the TRC references/incorporates in its consent conditions appropriate for a treatment system that relies on natural degradation of hydrocarbon-containing wastes – so that degradation can in fact occur, and so that it is not overwhelmed by excessive concentrations that might be toxic to the natural processes?*

This question overlaps with the following two questions. As the following two questions address the appropriateness of the consent conditions to protect the off-site environment during landfarming and to assure the final condition of the land, to avoid repetition the discussion here largely concentrates on consent conditions relating to contaminant input concentrations and soil loading rates.

The consent conditions typically impose requirements to:

- Prepare a management plan, although earlier consents did not have this requirement, and later consents have more detail required in the management plans, than earlier management plans. Details now required typically include:
  - notification procedures
  - procedures for the receipt and stockpiling of drilling wastes onto the site;
  - procedures for the management of stormwater recovered from, or discharging from, the drilling waste stockpiling area;
  - methods used for the mixing and testing of different waste types;
  - procedures for site preparation;
  - procedures for landfarming drilling wastes (including means of transfer from stockpiling area, means of spreading, and incorporation into the soil);
  - procedures for sowing landfarmed areas, post-landfarming management, monitoring and site reinstatement;
  - contingency procedures;
  - sampling regime and methodology;
  - control of site access; and
  - documentation for all the procedures and methods listed above.

- Notify the Council at least 48 hour prior to waste be brought on to site for stockpile and prior to application of waste to land for landfarming, with various specific details such as the waste composition required to be notified.
- Sample each type of waste for total petroleum hydrocarbons, BTEX, polycyclic aromatic hydrocarbons (PAHs) and chloride, nitrogen, pH, potassium and sodium.
- Keep records

These requirements generally cover the things required to control the process of landfarming. Earlier consents were less explicit in their requirements, however.

A gap in the information required in some earlier consents was that there was no explicit requirement for pre-disposal sampling of waste actually landfarmed; the only requirement being to sample waste coming onto the site with the apparent assumption that what came onto the site was the same as that landfarmed. With oil-based mud wastes likely to exceed allowable hydrocarbon loading rates without blending to reduce concentrations (noting that oil-based muds are seldom used now), the success of such blending is not explicitly required to be measured and reported in the earlier consents. However, the later consents viewed require the type of waste and concentrations of hydrocarbons, chlorides and nitrogen to be tested and notified before landfarming. This is an improvement on the earlier consents. It may be that the management plans of earlier consents covered the information gap but, if not, it is recommended that when sites with earlier consents, where landfarming is still active, come up for review, consideration be given to changing the notification conditions to more closely reflect current consents.

All consents viewed impose restrictions on the hydrocarbon concentrations, while earlier consents also imposed restrictions on nitrogen and chloride loading rates. Controls on these have presumably been set so that the hydrocarbons are not toxic to soil microbes, that nitrogen doesn't adversely affect groundwater and that high chloride (and associated sodium) does not affect the soil structure and pasture regrowth and result in excessive leaching to groundwater. In some later consents, for single applications of mud on sandy soil, restrictions on nitrogen and chloride were dispensed with in favour of not permitting any increase of contaminant concentrations in surface or groundwater except total dissolved salts, on the basis that high rainfall at these sites would result in flushing through of these contaminants.

For such a performance-based requirement to be effective requires (a) the consent holder to have sufficient knowledge about likely effects of particular waste loadings to ensure that groundwater or surface water is not contaminated and (b) sufficient, and sufficiently accurate, monitoring to demonstrate compliance. It is doubtful whether monitoring is frequent enough in all cases to demonstrate such compliance, particularly in sandy soils where effects could be rapid and have reduced by the time monitoring occurred; meanwhile an aquatic environment could have been affected. If Council compliance monitoring is stringent, the consent holder is forced to be cautious; otherwise the consent condition has less effect.

With respect to hydrocarbon loading rates, a combination of concentrations and mixing ratios (defined by depths of applied waste and cultivation depth) is intended to limit concentrations after mixing. Early consents (which are still active) required the following (edited to have consistent units with later conditions):

- *The rate of discharge shall be limited to an application spread depth of 150 mm prior to the wastes being incorporated into soil for waste solids with hydrocarbon content less than 50,000 mg/kg, or if hydrocarbon content of waste solids is equal or greater than 50,000 mg/kg the application spread depth shall be limited to 50 mm of waste solids prior to incorporation into soil.*
- *The hydrocarbon content in the waste prior to discharge at the site shall be less than 50,000 mg/kg, or if hydrocarbon level in the waste is equal or greater than 50,000 mg/kg the waste shall be incorporated into the soil so that the hydrocarbon content in the soil/waste mix shall be less than 50,000 anywhere in the surface 250 mm of soil after mixing.*

Ignoring the difference between volume ratios and mass ratios, and the probably different bulk densities of the waste and soil, the approximate effect of the first condition is to allow average concentrations after mixing of up to 30,000 mg/kg (a waste to soil mixing ratio of 1.5:1, or 150 mm in 250 mm total) for waste with less than 50,000 mg/kg hydrocarbons, while the effect of the two conditions together for higher concentration waste is to limit the applied waste concentration to 250,000 mg/kg, while achieving a concentration after mixing of no more than 50,000 mg/kg (a waste to soil mixing ratio of 1:4 or 50 mm in 250 mm total).

In practice, the Council does not expect hydrocarbon concentrations to exceed 100,000 mg/kg, which results in a maximum average hydrocarbon concentration after mixing of 20,000 mg/kg (pers. comm. Gary Bedford). This is probably a reasonable upper limit, and matches the upper concentration limit contained in Alberta, Canada's *Drilling Waste Management Directive 050* (ERCB, 2012) for treatment of drilling waste by biodegradation. The second consent condition does not then seem necessary, except if it is to allow a considerable leeway above the average from place to place. However, concentrations as high as 50,000 mg/kg (or even 30,000 mg/kg) are likely to be ecologically toxic, or at least inhibit bioremediation, and a lower upper limit is desirable. The applied concentrations and spreading and mixing should not be so inconsistent as to require a leeway of between 67% and 150% of the maximum average concentration expected.

While this issue is probably not particularly important for most wastes landfarmed, as the hydrocarbon concentrations are generally well below 50,000 mg/kg in the reports viewed, one of the monitoring reports supplied by TRC in fact has reported hydrocarbon concentrations in one drilling waste of 300,000 mg/kg and in another approaching 200,000 mg/kg. This means that, in practice, an average concentration after mixing of 50,000 mg/kg could result, which is inconsistent with both the 30,000 mg/kg maximum from one consent condition and the un-documented intent of 20,000 mg/kg maximum from another part of the condition.

Later consents have slightly different conditions; specifically:

- *For the purposes of landfarming, drilling wastes shall be applied to land in a layer not exceeding:*
  a) 100 mm thick for wastes with a hydrocarbon concentration less than 50,000 mg/kg dry weight;
  b) 50 mm thick for wastes with a hydrocarbon concentration equal to or greater than 50,000 mg/kg dry weight; and
  c) in a rate and manner such that no ponded liquids remain after one hour, for all wastes;

  prior to incorporation into the soil.

- *As soon as practicable following the application of solid drilling wastes to land, the consent holder shall incorporate the wastes into the soil to a depth of at least 250 mm.*

- *The hydrocarbon concentration in the soil over the landfarming area shall not exceed 50,000 mg/kg dry weight at any point where:*
  a) liquid waste has been discharged; or
  b) solid waste has been discharged and incorporated into the soil.

Again ignoring the difference between volume ratios and mass ratios, and the probable different bulk densities, mixing a 100 mm thick layer at a maximum of 50,000 mg/kg TPH, results in an average concentration of 20,000 mg/kg. This matches the Council's intent to have maximum concentrations after mixing of the order of 20,000 mg/kg and, as noted above, is in line with Alberta's *Directive 050*. However, the inconsistency noted above for higher concentration waste remains, allowing average concentrations after mixing as high 50,000 mg/kg, even though applied as a thinner layer.

If the intent is to ensure that average concentrations after mixing do not exceed 20,000 mg/kg, then a condition explicitly limiting the maximum applied concentration to 100,000 mg/kg should be applied. This means that wastes with high hydrocarbon concentrations (including oil-based mud wastes) may need to be blended with other wastes to

reduce concentrations. In addition, a leeway as high as 250% of the intended 20,000 mg/kg average should not be required if the application and tilling processes are well-controlled. It is suggested the maximum hydrocarbon concentration after soil mixing is reduced to 30,000 mg/kg.

As noted above, the reality is that in most cases concentrations will be well below the intended hydrocarbon limit after mixing. A review of the documents provided indicates that most wastes contain no more than a few thousand mg/kg of hydrocarbons. However, to cover all eventualities it is recommended that the Council reviews the current set of conditions imposing limits on hydrocarbon concentrations. A maximum average concentration of 20,000 mg/kg seems reasonable.

The possibility exists that mud-additives within drilling wastes, such as surfactants and biocides, are eco-toxic and therefore inhibit biodegradation. The Alberta Directive requires toxicity testing. The Council has considered this possibility and is currently carrying out a three-year study on sites landfarming a range of waste types, including historic oil-based muds, to assess landfarming effects on soil biota. The first year of the study has been formally reported in a publicly available report (TRC Technical Report 2011-35), while the results from the second year have been received but not reported. The results from both years show that any effects were subtle, if present at all, and could not be differentiated between the effects of physical site management and of possible low-level toxicity. The Council is also carrying out lab-based toxicity testing of synthetic and water-based muds and of hydraulic fracturing (fracking) fluids. At this stage there seems no need to consider toxicity testing of drilling wastes, but this should be reviewed when the studies are completed.

5.3 Off-site guidelines and standards

Question 3: *Are the various guidelines and standards that the TRC references/incorporates in its consent conditions appropriate for providing offsite environmental protection during the time degradation is occurring?*

The need for off-site protection revolves around protecting waterways or the coastal marine area, if applicable, from runoff, effects of erosion and discharge of contaminated groundwater, and protecting groundwater in its own right. A variety of methods are available:

- ensuring sites are appropriate for landfarming, e.g. without excessive slopes that could promote runoff and without very shallow groundwater (say <1 m);
- ensuring the waste is not excessively contaminated, whether in storage (or contain/line the storage sites) or when landfarmed;
- ensuring appropriate buffer distances to boundaries, water bodies and other sensitive environments;
- requiring stabilisation of the land after the landfarming is complete;
- monitoring nearby water bodies;
- monitoring groundwater; and
- applying standards to the water quality in water bodies or groundwater.

Such methods should be applied, in combination, on a case-by-case basis. Obviously, if there is no nearby waterbody, then no monitoring of surface water is necessary or possible. In general, such conditions are applied. However, some earlier consents did not require monitoring of groundwater, contrary to what is generally considered to be good practice. Instead, a generic condition was relied on:

> *The exercise of this consent shall not result in any adverse impacts on groundwater as a result of leaching, or on surface water including ecosystems, and/or result in a change to the suitability of use of the receiving water as determined by the Chief Executive, Taranaki Regional Council.*

Except in the case of gross, visible effects, and groundwater is not normally visible, such a condition is not capable of ensuring the outcome intended. The Council has recognised this and more recent consents have rather more explicit conditions:

> *Prior to the exercise of this consent, the consent holder shall after consultation with the Chief Executive, Taranaki Regional Council, install a minimum of three groundwater monitoring bores. The bores shall be at locations and to depths that enable monitoring to determine any change in groundwater quality resulting from the exercise of this consent.*

and:

> *Other than as provided for in condition 18* [which sets a Total Dissolved Solids standard]*, the exercise of this consent shall not result in any contaminant concentration, within surface water or groundwater, which after reasonable mixing, exceeds the background concentration for that particular contaminant.*

Depending on whether the monitoring wells are located appropriately, such conditions should ensure adequate protection of groundwater, although the point of compliance for reasonable mixing in groundwater (or in the case of hydrocarbons, attenuation, as mixing is not the only process occurring) can be difficult to define. It should be noted that a report prepared by Landcare Research for a particular landfarm (see Appendix A) found that groundwater concentrations of barium, various metals and possibly nitrogen (it is not clear) were above background concentrations. While this complied with the applicable consent, the site would not have complied if the wording above had applied.

The need for and location of wells will depend on the specifics of the proposal and the site. Storage pits in permeable soils, particularly if there is little buffer between the base of the pit and groundwater and/or in close proximity to a water body, or in close proximity to a shallow groundwater well, are obvious candidates for monitoring. Similarly, a landfarm on permeable soils with a shallow watertable is a candidate for groundwater monitoring of the landfarmed area. However, it is worth bearing in mind the process for assessing the sensitivity of groundwater contained in MfE (2011) when determining whether groundwater monitoring wells are required. Experience with hydrocarbon leaks from underground storage tanks has shown that hydrocarbon effects are seldom detectable beyond 100 m from the source. But some contaminants, such as sodium and chloride ions, and nitrate, either cannot degrade or degrade or transform only slowly, and also do not absorb onto aquifer materials (unlike many heavy metals), and are therefore subject to only dilution in groundwater.

In one of the monitoring reports reviewed, it is noted that pasture has not been successfully re-established on a landfarming site and further notes: "*While not a breach of consent conditions, the permanent establishment of pasture is an expected outcome of landfarming activities*". It is assumed that part of this expectation is to ensure the land is stabilised after landfarming to prevent erosion of the soil. If that is the case, incorporating a time limit of stabilisation of the land as a consent condition seems appropriate, rather than *"…resown to pasture [or into crop] as soon as practicable …"*. The consent dates from 2009. This condition has been changed in later consents (e.g. a consent dated 2012) to a more prescriptive time limit (two months) on reestablishment of vegetation, or if that is not possible, other measures to prevent erosion must be put in place. This approach is more appropriate.

5.4 End-point guidelines

Question 4: *Are the guidelines as applied in the consents appropriate for protecting potential subsequent use that might incorporate pastoral usage?*

There are several requirements to be met in the soil designed to protect subsequent use as farm land. These are:

- limits on soil electrical conductivity (Ec) "after landfarming", assumed to mean at the completion of the tilling process, as a different (lower) soil conductivity is required three months prior to the expiry of the consent

(maximum of 400 mS/m or, if background is in excess of that an increase of no more than 100 mS/m, and 290 mS/m at consent expiry).

- limits on the sodium adsorption ratio (SAR) after landfarming (maximum of 18 or if background is in excess of 18, an increase in SAR of no more than 1)
- limits on chloride, sodium and total soluble salts
- limits on heavy metals at all times to meet the Ministry for the Environment-endorsed New Zealand biosolids guidelines, published by the New Zealand Water and Waste Association (now Water New Zealand) (NZWWA, 2003).
- limits on hydrocarbons prior to the consent expiry from the 1999 version of the Ministry for the Environment's Petroleum Hydrocarbon Guidelines, although now republished in 2011 with minor revisions (MfE, 2011).

The soil Ec and the SAR limits have been taken from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000). These limits relate to irrigation water, rather than the Ec and SAR within soil. It is also not clear how the soil conductivity is to be measured, as there are a number of methods, and how a soil measurement should be related to limits within irrigation water. While the current limits may be appropriate, it would be worth reviewing the applicability and also clarifying the methods of measurement.

The limits on heavy metals from the *Biosolids Guidelines* are generally appropriate. The values are "pollute up to" limits and have generally been derived from phytotoxicity considerations, i.e. ensuring the ground will continue to grow things. The 2003 version of the Guidelines is the current document. It should be noted, however, that the soil contaminant standards (SCS) derived to support, and referenced by, the *Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011* (the NES) are, for some land uses, lower than the *Biosolids Guidelines* for arsenic and lead. The lead SCS for both the rural residential and standard residential land use scenarios are lower than the biosolids limit, and the arsenic SCS for the rural residential scenario is lower than the biosolids limit.

While the NES does not generally apply to production land (which includes farm land) as defined in the RMA, the NES does apply to residential land within production land. The NES would also apply if at some future time the landfarmed area was changed to residential use. It is recommended the Council review the end-point values for both arsenic and lead to determine whether they should be consistent with the values referenced by the NES.

Monitoring results show the heavy metal concentrations of the wastes disposed in the Taranaki region are generally low, and there seems little likelihood of the limits, whether current or modified as suggested, being exceeded.

A different philosophical approach to that of the biosolids heavy metal limits has been taken for hydrocarbon limits in using the soil guideline values for an agricultural use scenario from *the Petroleum Hydrocarbon Guidelines* (MfE, 2011). These values are based on human health considerations, not protection of the productive capacity of the soil. In addition, the hydrocarbon guidelines were never intended to be "pollute up to" values (pers. comm., James Court, formerly MfE contaminated land policy adviser); rather they are intended to assess the risk to human health of already damaged land. Typically, "pollute up to" values are lower than values intended for assessing whether the risk of existing contaminated land is acceptable. The values may or may not be protective of the productive capacity of the soil.

New Zealand, in common with most jurisdictions, does not have the equivalent of the *Biosolids Guidelines* for hydrocarbons. However, Canada's soil quality guideline derivation methodology includes consideration of protecting the productive capacity of soil. Given there is a joint intention by MfE and the oil industry within New Zealand to review and revise the MfE (2011) *Petroleum Hydrocarbon Guidelines* to bring them into line with the derivation methodology used to derive the SCSs referenced by the NES, and that there probably will not be an agricultural use scenario in the same sense as the current agricultural scenario, it is worth considering whether the Canadian

hydrocarbon guidelines (CCME, 2008) would be applicable as landfarming endpoints. In addition, the United States Environmental Protection Agency (US EPA) has issued Ecological Soil Screening Limits for polycyclic aromatic hydrocarbons (US EPA, 2007). While there are no values to protect terrestrial plants, the values to protect soil invertebrates may be worth considering. It is noted that the Council has engaged Landcare Research to consider hydrocarbon limits for agricultural land.

Consent limits have not been applied to barium. Barium appears in drilling muds as the insoluble barium sulphate (barite). The Council carried out a study of the literature some years ago (Gary Bedford, pers. comm.) and decided that limits were not necessary. PDP has independently reviewed the literature and considers that decision to be appropriate. Barium is only moderately toxic and in the form of barite has a low toxicity, as its low solubility results in low bioavailability.

5.5 Monitoring

Question 5: *Is the nature, scale and scope of the monitoring (taking the Council and consent holder's requirements together) a scientifically and technically sound programme that can be considered to offer reasonable certainty about the environmental state of each area?*

In general, the combination of the monitoring required in more recent consents and the compliance monitoring the Council undertakes provides reasonably thorough information on the environmental state of each area. This includes consideration of the breadth of contaminants monitored, the environmental media sampled and the frequency of sampling. However, the detail of particular sites has not been considered here, being beyond the scope of this review.

Some earlier consents have less robust monitoring regimes, in that groundwater monitoring wells were not required as a consent condition. The Council has recognised this deficiency and all active landfarming sites now have groundwater monitoring in place. It is, however, appropriate to consider the need for groundwater monitoring on a case-by-case basis, as such monitoring is not necessarily required in all cases. Sites that will not take high-concentration wastes, or have low permeability soils with no water bodies in close proximity, may not require groundwater monitoring.

A reservation with the sampling of landfarmed areas is the practice of analysing composite soil samples of up to 10 sub-samples. While this method is good for determining an average concentration, if the composite is properly homogenised, it is poor practice to homogenise samples intended for hydrocarbon analysis as the homogenising process may result in a loss of volatile hydrocarbon components. If not homogenised, it is doubtful whether the 1 to 3 g actually analysed by the laboratory will be properly representative of the samples taken, let alone the sampled area. This is probably not important where the sample results are well below the applicable limits, and most waste except oil-based mud wastes are likely to be well below the hydrocarbon application limits, but it could be important where high hydrocarbon concentrations are present. Consideration should be given to analysing a larger number of individual samples, rather than composite samples.

5.6 TRC Reporting

Question 6: *Does the Council accurately and fairly report the implications of the results of monitoring, in terms of both consent compliance and of environmental effects?*

Within the limitations of some of the monitoring (see previous section) the annual monitoring reports appear to contain a good description of the activities occurring on the sites, and the effects, or lack of, from those activities. Assessing consent compliance against a checklist of consent conditions, and then determining an overall compliance score, appears to be both fair and accurate.

5.7 Should landfarming be allowed to continue

Question 7: *Based on either what you generally know of the behaviour of hydrocarbons in soil, or on what you find in your review of the consents and reports that the Council is providing, is there any sound and evidence–based reason why the practice of land-farming should or should not be allowed to continue in Taranaki?*

As noted in the discussion on Question 1, landfarming is technically feasible provided the soil is not overloaded. Whether it should be allowed is a matter of policy and how it is controlled. If controlled properly, there is no reason why landfarming should not be allowed. The devil, of course, is in the detail of the control and ensuring each application for landfarming is treated on a case-by-case basis. There will be some proposed sites where landfarming would be undesirable, because of such things as soil types, shallow depth to groundwater or proximity to vulnerable environments, combined with high concentrations of hydrocarbons within the wastes proposed to be landfarmed.

The Council has exercised less control than desirable in some of the earlier consents granted in relation to allowable loading rates, the types of sites and the monitoring of groundwater. However, in general, the nature of the waste appears to be such that the actual loading rates have probably not been so high as to create problems for the biodegradation process or the final soil condition, or to the wider environment in general. In addition, the Council has recognised a need to impose tighter controls, with more recent consents requiring groundwater monitoring, and also recognised the gap in information with respect to the toxicity of the waste by carrying out some research which could result in modified loading rates.

Viewed as a whole, the landfarming process seems to be both reasonably well conducted by site operators (although it is understood the Council has taken action against some operations when non-compliance was observed) and monitored by the Council. Given this, and subject to the Council continuing to review general and site-specific consent conditions and landfarming practices to reflect experience gained, there seems no reason why landfarming of hydrocarbon-containing wastes should not continue. As at present, each proposal should be considered on its merits as a discretionary activity and either turned down, or allowed with controls imposed appropriate to the particular circumstances.

5.8 Other matters

Question 8: *Is there any other matter that you consider the Council should be made aware of, in relation to the matter of consenting and monitoring the land application and treatment of hydrocarbon-bearing waste in the region?*

Drilling wastes are stockpiled within storage pits, before possibly being blended and then applied to the land. None of the consents reviewed had explicit requirements for the pits to be lined to prevent effects on groundwater, or bunding to prevent overflow, or explicit requirements to control stormwater around the pits or the landfarm in general (although it is understood that the Council has now required all storage pits to be lined). The consents appear to rely on controls on off-site discharge quality, i.e. performance controls, and the need to prepare, and have approved, management plans, although a management plan is not required by every consent.

In one of the two consent applications sighted, and in the single management plan seen (the plan prepared by the same company and for the same site) there was information on the storage pits and stormwater control measures, giving some confidence that pits and stormwater controls would perform as intended. In addition, information in monitoring reports for some sites indicated pits on that site were lined (although overflows were also noted). In discussions with the Council (pers. comm. Gary Bedford) it would seem that the Council has developed reasonable confidence that most landfarming operators will design and operate the storage pits and landfarms in a reasonable and responsible manner. This non-prescriptive approach is in contrast with the approach taken by Alberta's *Directive 050* (ERCB, 2012). This Directive is the latest version of the original 1996 document which the Council drew on in its own 2005 waste disposal guideline (TRC, 2005).

There is a question of whether landfarming sites should be listed on the Council's Selected Land Use Register – currently the sites do not appear as such on the Taranaki Regional Xplorer on-line Geographical Information System (GIS) – and whether the contaminated land NES applies to landfarming sites. This is a legal issue which the Council, along with the territorial local authorities within the Taranaki Region may wish to consider. This is not strictly an issue for the Council as the regulations are administered by the relevant territorial authority, however, there is an expectation in the NES regulations that the territorial authority will use information available to it from the regional council if the NES does apply.

On the face of it, landfarming sites fit under HAIL[1] category G-5 *Waste disposal to land (excluding where biosolids have been used as soil conditioners)* or even G-6 *Waste recycling or waste or wastewater treatment*, and therefore may be captured by the regulations. The regulations do not apply if the land is production land, e.g. farm land, however there is a question of whether the land is actually production land during the landfarming operation. If not, the land may require consent for land disturbance, although there is a paradox in that the land is not contaminated until the land farming operation commences. Regardless, if the land was to be subsequently used for some purpose other than production land, or if a house was to be constructed within the production land, then the NES may well apply.

It is recommended that legal advice be sought on this matter and, if appropriate, the sites be placed on the Council's Selected Land Use Register and the relevant territorial authority notified.

6.0 Conclusions and Recommendations

A review of consent conditions and monitoring results for a number of landfarms being used to bioremediate hydrocarbon-wastes from the oil exploration and production industry has been carried out. The broad intent of the review was to determine whether landfarming wastes is an environmentally viable thing to do and, if so, whether the process is being managed appropriately by the Council. The review is not an audit of specific landfarming operations, nor an audit of Council's actions with respect to specific landfarms.

In general, the review has found landfarming of oily wastes is an appropriate and sustainable means of dealing with the wastes. In addition, the controls imposed seem, with some exceptions, generally appropriate. While some of the earlier consent conditions displayed some deficiencies, particularly the absence of specific groundwater monitoring requirements, requirements to report contaminant concentrations of wastes applied to land, rather than just that received into storage, and no requirement to line storage pits, the Council has worked to update the standard consent conditions and also revise requirements for active landfarms. All active landfarms now have groundwater monitoring and lined storage pits. However, within the limited extent that particular consent and compliance reports were sighted during this review, no evidence was seen suggesting significant adverse effects have occurred from past landfarming activities in compliance with their consents.

Notwithstanding the revised groundwater monitoring and pit lining requirements, there are some other more minor matters in older consents that are less stringent than some more recent consents. It is therefore recommended that the Council review the older but still active landfarming consents as the opportunity arises (i.e. as review dates in the consents fall due, if a review is not possible otherwise) and, as appropriate, impose conditions consistent with the more recent consents.

There is a question as to whether the current hydrocarbon limits for waste applied to land are appropriate. The intent is to achieve no more than 20,000 mg/kg TPH after mixing into the soil, but the wording of the consents suggests that a maximum of up to 50,000 mg/kg would be permissible. A hydrocarbon concentration up to 50,000 mg/kg could inhibit the bioremediation process, being possibly toxic to soil microorganisms. The reality is that, in general,

[1] Hazardous Activities and Industries List – see http://www.mfe.govt.nz/issues/hazardous/contaminated/hazardous-activities-industries-list.html

hydrocarbon concentrations are much lower than the consented limits and therefore a toxicity issue probably does not arise. However, it is recommended for future consents that the wording be changed so that, on average, TPH is no more than 20,000 mg/kg after mixing into the surface soil, with no more than 30,000 mg/kg at any location.

There is also a question whether various mud additives could be toxic, inhibiting bioremediation, reducing soil biodiversity and affecting the subsequent reuse of the land for pasture or crops. The Council is currently carrying out research which should help answer the question, and presumably lead to modified consent conditions if necessary. Interim results suggest mud additives are not contributing to significant toxic effects.

The consented heavy metal end-points after landfarming are appropriate for protection of the productive capacity of agricultural land. However, consideration should be given to adopting the lower human health NES standards for arsenic and lead to cover the possibility that the land use may change in the future. Given the heavy metal concentrations in the waste are not particularly elevated, the consent limits are unlikely to be exceeded.

The hydrocarbon guidelines being employed as landfarming end-points are derived considering human health only, not the protection of productive capacity of the land or the soil flora or fauna, and are therefore out of step with the heavy metal limits. It is understood the Council has engaged expert advisers to recommend hydrocarbon guidelines specifically intended for protection of agricultural land. This is appropriate.

Finally, it is recommended that the Council seek legal advice on the implications for landfarm sites of the recently implemented NES, and whether there is a need to list landfarm sites on the Council's SLUR as HAIL sites. As district councils in the region are required to administer the NES, these councils should also be consulted.

7.0 Limitations

This report has been prepared on the basis of information provided by the Taranaki Regional Council. PDP has not independently verified the provided information and has relied on it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

The interpretations contained within this report where they relate to sample information apply to the dates of those samples. With time, the site conditions and environmental standards could change so that the reported assessment and conclusions are no longer valid. Accordingly, the report should not be used to refer to site conditions and environmental standards applying at a later date without first confirming the validity of the information at that time.

This report has been prepared by PDP on the specific instructions of the Taranaki Regional Council for the limited purposes described in the report. PDP accepts no liability to any other person for their use of or reliance on this report, and any such use or reliance will be solely at their own risk.

Yours sincerely

PATTLE DELAMORE PARTNERS LIMITED

Graeme Proffitt

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ERCB (2012) *Drilling Waste Management*, ERCB Directive 050, Revised Edition May 2, 2012, Energy Resource Conservation Board, Alberta, Canada http://www.ercb.ca/regulations-and-directives/directives/directive050, accessed February 2013

MfE (2011) *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand (Revised 2011)*, Ministry for the Environment, Wellington.

NZWWA (2003) *Guidelines for the Safe Application of Biosolids to Land in New Zealand*, New Zealand Water and Waste Association, Wellington.

TRC (2005) *Guidelines for the control of disposal of drilling wastes onto and into land*. Taranaki Regional Council, http://www.trc.govt.nz/recycling-and-waste-2/, accessed February 2012.

US EPA (2007) *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs)*, Interim Final, OSWER Directive 9285.7-78, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington DC.

Appendix A – Documents Provided by TRC

TRC Monitoring Reports and Associated Resource Consents

Greymouth Petroleum Hawera Landfarm Monitoring Programmes Annual Report 2010-2011, Technical Report 2011-31, Taranaki Regional Council, October 2011. (Relates to discharge permit 6236-1)

Origin Energy Resources Limited Drilling Waste Landfarms Monitoring Programmes Annual Report 2010-2011, Technical Report 2011-49, Taranaki Regional Council, January 2012 (Relates to discharge permits 5325-1, 5935-1, 6135-1 and 6297-2)

C Boyd – Drilling Waste Disposal Monitoring Programmes Annual Report 2010-2011, Technical Report 2011-48, Taranaki Regional Council, March 2012 (Relates to discharge permits 7559-1, 7591-1, 6900-1 and 6900-2)

BTW Company Limited Brown Road Landfarm Monitoring Programmes Annual Report 2010-2011, Technical Report 2011-60, Taranaki Regional Council, March 2012. (Relates to discharge permits 6867-1 and 7670-1)

TRC Resource Consents (in addition to those attached to monitoring reports)

Consent 7795-1 Discharge Permit, Remediation (NZ) Limited – Manawapou Road, Manutahi

Other TRC Reports

Land farming of drilling waste: Impacts on soil biota within sandy soils in Taranaki (Year 1 of 3), Technical Report 2011-35, Taranaki Regional Council, October 2011.

Resource Consent Applications

Application for Resource Consent, Landfarming of Cutting from water and synthetic-based muds from hydrocarbon exploration and production activities, Spence Road, Kakaramea. BTW Company Limited, 28 September 2011

Assessment of Environmental Effects, Surrey Road Landfarm (proposed). M-I SWACO, October 2009.

Management Plans

Landfarm Management Plan, Surrey Road Landfarm, Inglewood, M-I SWACO, November 2009

Monitoring Programmes

Boyd Landspreading – Surrey Road Landfarms Limited, Consent 7591-1 2012/2013

BTW Oeo Landfarm – BTW Company Limited, Consent 7613-1 2012/2013

Boyd – Derby Road North Stockpiling Site – DC Boyd, Consents 6900-2, 7911-1 2012/13

Other Information Provided by TRC

Swift Energy New Zealand Ltd – Review of Land Disposal and Remediation of Oil-based Drilling Muds, Southern Coastal Taranaki, Report to BTW Surveyors by C Ross, Landcare Research Limited, 25 February 2005

Review of arsenic and lead criteria in land farming consents

The Council commissioned PDP to review the conditions imposed through consents on the activity of landfarming. One recommendation made within the PDP review was to evaluate the criteria being used for arsenic and for lead within soil following the application of drilling wastes.

The discussion of this matter within the PDP report is set out below.

The limits on heavy metals from the Biosolids Guidelines are generally appropriate. The values are "pollute up to" limits and have generally been derived from phytotoxicity considerations, i.e. ensuring the ground will continue to grow things. The 2003 version of the Guidelines is the current document.

It should be noted, however, that the soil contaminant standards (SCS) derived to support, and referenced by, the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (the NES) are, for some land uses, lower than the Biosolids Guidelines for arsenic and lead. The lead SCS for both the rural residential and standard residential land use scenarios are lower than the biosolids limit, and the arsenic SCS for the rural residential scenario is lower than the biosolids limit.

While the NES does not generally apply to production land (which includes farm land) as defined in the RMA, the NES does apply to residential land within production land. The NES would also apply if at some future time the landfarmed area was changed to residential use. It is recommended the Council review the end-point values for both arsenic and lead to determine whether they should be consistent with the values referenced by the NES.

Monitoring results show the heavy metal concentrations of the wastes disposed in the Taranaki region are generally low, and there seems little likelihood of the limits, whether current or modified as suggested, being exceeded.

Table 1: relevant soil criteria

Soil criteria	Arsenic mg/kg	Lead mg/kg
Biosolids (current consent conditions)	20	300
NES- rural residential (25% of diet produced on-site)	17	160
NES- industrial unpaved	70	3,300
Typical landfarm values (after incorporation)	2- 5	2.7- 6.2
Wastes prior to incorporation	0.0024- 5	0.023-72 (all results except 1 were <37)

Following completion of site usage as a land farm, conventional practice is for restoration to agricultural (pastoral) usage. The NES does not apply in such circumstances. Given that the Biosolids guidelines are focused on the productivity (health) of soil, the current criteria being used by the Council remain the most valid for consent surrender criteria.

The NES criteria for rural residential land use would apply only in the situation of a former land farm subsequently being converted to rural residential use. This situation is not envisaged to occur in Taranaki, when existing land farm sites are considered. There is simply no driver for conversions of this nature in the vicinity of land farm sites. It is however acknowledged that the possibility cannot be excluded in perpetuity.

From data received or determined by analysis by the Council to date, compliance with the NES criteria for rural residential use would pose no issues for land farm operators. It would demonstrate we are taking a very conservative approach to protecting future potential uses and maximizing the number of options for purpose to which land might be applied. Alternatively, the biosolids criteria for As and Pb could remain in use given that the Council's public information systems identify areas that have been used for landfarming and thus would allow further evaluation at the time of any subdivision. However, adopting the NES provides the more conservative approach as a default position.

For other heavy metals, the biosolids criteria remain the more stringent (see Table 2). [The NES has a more conservative limit for chromium, but this applies only if it is in the form of Cr (VI). See note to table].

It is therefore recommended that future landfarm discharge consents should incorporate the NES criteria for rural land use, rather than the biosolids criteria, as a default position in respect of arsenic (17 mg/kg) and lead (160 mg/kg).

Table 2: biosolids and NES criteria for heavy metals other than As, Pb

Soil criteria	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Mercury mg/kg	Nickel mg/kg	Zinc mg/kg
Biosolids (current consent conditions)	1	600	100	1	60	300
NES- rural residential (25% of diet produced on-site)	>0.8 (pH dependent)	290*	>10,000	200	-	-

*(Comment from PDP) *This is for Cr(VI). It is highly unlikely that Cr(VI) would exist after land farming. If Cr(Vi) existed in the first place it would be converted to trivalent forms unless there were highly unusual soil conditions. Trivalent Cr is not very toxic. Sticking with Biosolids is probably the better way of going, rather than using Cr(VI) value from NES.*

Gary Bedford
Director-Environment Quality

Review of landfarming consent conditions hydrocarbons (TPH, PAH, BTEX)

The Council commissioned PDP to review the conditions imposed through consents on the activity of landfarming. One recommendation made within the PDP review was to evaluate the criteria being used the loading rates of hydrocarbon-containing wastes to land following the application of drilling wastes, while another addressed the appropriateness of surrender conditions (concentrations of hydrocarbon that might still remain within soil at the time of surrender or expiry of a consent)..

Loading rate:

The discussion of the matter within the PDP report suggested that the Council review conditions to ensure that a maximum average concentration of 20,000 mg/kg in soil is achieved. The full text is set out below.

In practice, the Council does not expect hydrocarbon concentrations to exceed 100,000 mg/kg, which results in a maximum average hydrocarbon concentration after mixing of 20,000 mg/kg (pers. comm. Gary Bedford). This is probably a reasonable upper limit, and matches the upper concentration limit contained in Alberta, Canada's Drilling Waste Management Directive 050 (ERCB, 2012) for treatment of drilling waste by biodegradation. The second consent condition does not then seem necessary, except if it is to allow a considerable leeway above the average from place to place. However, concentrations as high as 50,000 mg/kg (or even 30,000 mg/kg) are likely to be ecologically toxic, or at least inhibit bioremediation, and a lower upper limit is desirable. The applied concentrations and spreading and mixing should not be so inconsistent as to require a leeway of between 67% and 150% of the maximum average concentration expected.

While this issue is probably not particularly important for most wastes landfarmed, as the hydrocarbon concentrations are generally well below 50,000 mg/kg in the reports viewed, one of the monitoring reports supplied by TRC in fact has reported hydrocarbon concentrations in one drilling waste of 300,000 mg/kg and in another approaching 200,000 mg/kg. This means that, in practice, an average concentration after mixing of 50,000 mg/kg could result, which is inconsistent with both the 30,000 mg/kg maximum from one consent condition and the un-documented intent of 20,000 mg/kg maximum from another part of the condition.

Later consents have slightly different conditions; specifically:

> *For the purposes of landfarming, drilling wastes shall be applied to land in a layer not exceeding:*
> *a) 100 mm thick for wastes with a hydrocarbon concentration less than 50,000 mg/kg dry weight;*
> *b) 50 mm thick for wastes with a hydrocarbon concentration equal to or greater than 50,000 mg/kg dry weight; and*
> *c) in a rate and manner such that no ponded liquids remain after one hour, for all wastes; prior to incorporation into the soil.*
>
> *As soon as practicable following the application of solid drilling wastes to land, the consent holder shall incorporate the wastes into the soil to a depth of at least 250 mm.*
>
> *The hydrocarbon concentration in the soil over the landfarming area shall not exceed 50,000 mg/kg dry weight at any point where:*
> *a) liquid waste has been discharged; or*
> *b) solid waste has been discharged and incorporated into the soil.*

Again ignoring the difference between volume ratios and mass ratios, and the probable different bulk densities, mixing a 100 mm thick layer at a maximum of 50,000 mg/kg TPH, results in an average concentration of 20,000 mg/kg.

This matches the Council's intent to have maximum concentrations after mixing of the order of 20,000 mg/kg and, as noted above, is in line with Alberta's Directive 050. However, the inconsistency noted above for higher concentration waste remains, allowing average concentrations after mixing as high as 50,000 mg/kg, even though applied as a thinner layer.

If the intent is to ensure that average concentrations after mixing do not exceed 20,000 mg/kg, then a condition explicitly limiting the maximum applied concentration to 100,000 mg/kg should be applied. This means that wastes with high hydrocarbon concentrations (including oil-based mud wastes) may need to be blended with other wastes to reduce concentrations. In addition, a leeway as high as 250% of the intended 20,000 mg/kg average should not be required if the application and tilling processes are well-controlled. It is suggested the maximum hydrocarbon concentration after soil mixing is reduced to 30,000 mg/kg.

As noted above, the reality is that in most cases concentrations will be well below the intended hydrocarbon limit after mixing. A review of the documents provided indicates that most wastes contain no more than a few thousand mg/kg of hydrocarbons. However, to cover all eventualities it is recommended that the Council reviews the current set of conditions imposing limits on hydrocarbon concentrations. A maximum average concentration of 20,000 mg/kg seems reasonable.

In line with the review's recommendation, it is proposed that in future consents, the maximum hydrocarbon concentration in the soil over the landfarming area should not exceed 20,000 mg/kg dry weight (reduced from 50,000 mg/kg or 30,000 mg/kg in existing consents). This ensures regulatory consistency with the Alberta Directive regardless of the fact that there is already existing consistency in practice.

Surrender conditions:

The PDP review suggested that the Council should review the criteria applied to residual hydrocarbons remaining in situ at the time of expiry or surrender of the consent. The full text is as follows:

the Council should review the applicability of the current human-health-based hydrocarbon limits at the time of consent expiry, rather than ecologically-based limits. It is understood the Council is currently seeking expert advice on this issue.

A different philosophical approach to that of the biosolids heavy metal limits has been taken for hydrocarbon limits in using the soil guideline values for an agricultural use scenario from the Petroleum Hydrocarbon Guidelines (MfE, 2011). These values are based on human health considerations, not protection of the productive capacity of the soil.

In addition, the hydrocarbon guidelines were never intended to be "pollute up to" values (pers. comm., James Court, formerly MfE contaminated land policy adviser); rather they are intended to assess the risk to human health of already damaged land. Typically, "pollute up to" values are lower than values intended for assessing whether the risk of existing contaminated land is acceptable.

Canada's soil quality guideline derivation methodology includes consideration of protecting the productive capacity of soil. Given there is a joint intention by MfE and the oil industry within New Zealand to review and revise the MfE (2011) Petroleum Hydrocarbon Guidelines to bring them

into line with the derivation methodology used to derive the SCSs referenced by the NES, and that there probably will not be an agricultural use scenario in the same sense as the current agricultural scenario, it is worth considering whether the Canadian hydrocarbon guidelines (CCME, 2008) would be applicable as landfarming endpoints.

Table 1: Agricultural land use criteria for hydrocarbons

Fraction				
CCME Coarse grained	C6-C10	C11-C16	C17-C34	C35+
Hydrocarbons, mg/kg	210	150	300	2800
MfE Sandy soil, <1 m deep	C7-C9	C10-C14	C15-C36	-
Hydrocarbons, mg/kg	120	58	4,000	-
Typical landfarm soil levels at time of surrender mg/kg (per 1229880)	<8- <11	<20- <30	<40- 187	-

GP Comment: The 30 mg/kg value from CCME is for protection of human health via the inhalation pathway. The ecological direct contact value is 210 mg/kg (see CCME, 2008) and is the appropriate value here. 210 mg/kg is used for both coarse and fine-grained soils, as is 150 mg/kg for the C11 – C16 fraction. In the Canadian context, eco-direct contact is contact between plant roots or soil invertebrates and the contaminated soils, with the intent being to preserve the principal ecological functions performed by the soil resource. The 25th percent effects level is used, which means there could be effects in some more sensitive plants or soil invertebrates.[1]

The values for the two heavier fractions are for the eco pathway, which is the critical situation (given these fractions are not very toxic to people and these fractions are not volatile).

For the lightest fraction (which given the volatilisation and biodegradation processes at work in landfarming will be the fraction with the highest expected percentage loss), and the C17-C34 fraction or its approximate equivalent in the MfE criteria, the CCME criteria are considerably more stringent.

GP comment: While coastal sandy soils would probably fit within the coarse soil category (median grain size >0.075 mm), other soils could be finer and it would be advantageous to use the less stringent fine soil criteria for the heavier fractions.

For the MfE C10-C14 fraction, it should be noted that this is referenced by MfE as a trigger value for further investigation specifically of PAH concentrations (eg naphthalene). CCME carries no such rider. In other words, exceedance of the MfE C10-C14 value does not of itself constitute a requirement to control land use. The CCME criterion carries no such qualifier ie it is absolute in its own right. Given that the Council has to date referenced both TPH and

[1] *Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale, Supporting Technical Document*, Canadian Council of Ministers of the Environment, January 2008 http://www.ccme.ca/ourwork/soil.html?category_id=43

the PAH criteria separately, the use of the 58 mg/kg does not impose a penalty other than the need to do additional soil analyses. The Council could either and equally, continue to require the MfE criteria for TPH and PAH jointly, or alternatively could impose a single absolute limit for a C11-C16 fraction consistent with the CCME criterion.

GP comment: The CCME TPH values are not intended to cover PAHs. These should be addressed separately. Remediation to meet the TPH standards will not necessarily mean that the PAH soil quality guidelines will be met, and vice versa.[2]

Unfortunately, the Canadian have recently derived values for only three PAHs, and old provisional numbers for some others. I don't see the point in using the old provisional numbers because if they couldn't find enough data to derive new numbers why would you want to go for the old numbers which presumably are based on even less information. Their policy basis is very shaky.

The numbers they do have for protection of soil invertebrates and plants are:

- Anthracene: 2.5 mg·kg-1
- Fluoranthene: 50 mg·kg-1
- Benzo[a]pyrene: 20 mg·kg-1

They also have some numbers for protection of grazing animals. These are in the 100s and 1000s of mg/kg for dairy cows, the only animal relevant for NZ.

In using the Canadian TPH values, as TPH will also pick up PAHs, if the PAHs are at significant concentrations the PAH concentrations should be subtracted off the TPH values. This, in effect, means the TPH values will be less conservative. Naphthalene is subtracted from the F2 result, while phenanthrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene and pyrene should be subtracted from the F3 result. That's with the Canadian analytical method. It might be slightly different for the NZ TPH method – I haven't checked the carbon numbers in each of those PAHs.

The US EPA also has Eco-SSL for PAHs, but they divide into two ranges. Reference is here: http://www.epa.gov/ecotox/ecossl/ - pdf at bottom right of page. The values are below. The relevant ones are for soil invertebrates. I think the mammalian values are for ground-dwelling animals such as voles – not very relevant.

Table 2.1 PAH Eco-SSLs (mg/kg dry weight in soil)

			Wildlife	
	Plants	**Soil Invertebrates**	**Avian**	**Mammalian**
Low Molecular Weight (LMW)	NA	29	NA	100
High Molecular Weight (HMW)	NA	18	NA	1.1

[2] *Canadian Soil Quality Guidelines, Carcinogenic And Other Polycyclic Aromatic Hydrocarbons (PAHs) (Environmental and Human Health Effects) Scientific Criteria Document* Canadian Council of Ministers of the Environment, 2010 http://www.ccme.ca/publications/cegg_rcqe.html?category_id=125

NA = Not Available. Data were insufficient to derive an Eco-SSL.

Unfortunately they don't make it simple to find out what their definitions of low and high molecular weight is. You have to delve into the appendices, which I haven't bothered doing.

For either option there is no apparent change in respect of anticipated compliance. The one point to note if the CCME criteria are used, is that laboratories in NZ are analyzing and reporting in terms of the MfE criteria, and so for example would include extra results if the C15-C36 fraction result was used to assess compliance with the C17-C34 result. Conversely, a C7-C9 result reported by a NZ laboratory would under-report a compliance result for a CCME C6-C10 criterion.

GP Comment: As you have noted, the carbon ranges for the MfE and CCME TPH methods do not align. I don't think there is any easy way of getting them to align, as it depends on the particular mixture. Drilling wastes are probably towards the heavy end of the spectrum. I guess you could crudely (no pun intended) assume that there was roughly the same concentration of each carbon number in the C15-C36 range and adjust it downwards by 17/21, or alternatively adjust the CCME C17-C34 value upwards by 21/17. I wouldn't bother about the C6-C9 discrepancy. There shouldn't be much in the way of light end anyway; not after landfarming. That leaves C10-C14 vs C11-C16. Again, I wouldn't have thought there would be a lot at the lighter end of this range but there could be towards the top. Again, ignore.

Recommendation: given that the CCME criteria are based on consideration of both human health and ecological effects, while the MfE criteria relate only to human health, the CCME criteria should be adopted for end-of-exercise conditions within future consents for land farming activities as the default values.

Graeme Proffitt BE(Hons)(Civil), PhD(Civil Eng), MIPENZ

Expertise

- Investigation, assessment and management of contaminated land
- Waste treatment and disposal
- Environmental policy development
- Water resources investigations
- Construction and project management

Nationality

- New Zealander

Qualifications

- BE(Hons)(Civil), 1976, University of Canterbury
- PhD(Civil Eng), 1980, University of Canterbury
- Dip Bus St, 1988, Massey University
- MIPENZ

Professional Affiliations

- Institution of Professional Engineers NZ
- Waste Management Institute of New Zealand
- Water New Zealand
- Resource Management Law Association
- New Zealand Geotechnical Society
- IPWEA NZ
- National Ground Water Association (USA)

Employment Record

- 1993 – Present
  Director
  Pattle Delamore Partners Ltd, Wellington
- 1992 - 1993
  Senior Engineer
  Clyde Power Project, Electricity Corporation of NZ, Clyde
- 1990 - 1992
  Monitoring Manager
  Clyde Power Project, Works Consultancy Services, Cromwell
- 1987 - 1990
  Inspection Engineer
  Clyde Power Project, Works Consultancy Services, Cromwell
- 1984 - 1986
  Investigations Engineer
  Clutha Valley Development, Ministry of Works and Development, Cromwell
- 1981 - 1984
  Senior Engineer
  Tongariro Power Development, Ministry of Works and Development, Turangi

EXPERIENCE

Dr Graeme Proffitt, a director of PDP, is a civil engineer with more than 30 years' experience in contaminated site investigation and management, water resources investigation, environmental engineering, geotechnical site investigation, and construction management. After completing his PhD in the fluid mechanics of gravel-bed rivers, Graeme spent 13 years on hydroelectricity development projects, including environmental investigations, construction management and a very large scale instrumentation and monitoring project. For the last 19 years he has specialised in environmental engineering and resource management, principally contaminated land assessment, remediation and management, but also groundwater investigation, monitoring and development, and hazardous waste disposal.

In his contaminated land work Graeme has planned, carried out or supervised projects ranging from simple desktop studies through to complex site management or remediation. He has an intimate knowledge of New Zealand and overseas guidelines and risk assessment methodologies and has advised a wide range of industrial, commercial, land development and central and local government clients on contaminated site assessment, redevelopment and management strategies.

As a nationally recognised expert, Graeme has been a principal adviser to public health services throughout New Zealand and assisted central government authorities develop policy and regulatory instruments for contaminated land matters. He has appeared as an expert at local authority planning and Environment Court hearings and is familiar with the resource consenting process and the requirements of the Resource Management Act 1991 and the Health and Safety in Employment Act 1989.

PROJECT EXPERIENCE

Several hundred projects involving investigation of land, groundwater and surface water contaminated with chemicals related to petroleum, gasworks, timber treatment, waste disposal, chemical processing, metal smelting, agriculture, horticulture, pesticide and pest control, and manufacturing industries. Provided advice to central and local government and industry.

Policy development for the Ministry for the Environment, including the 2011 National Environmental Standard (NES) for Assessing and Managing Contaminants in Soil, preparation of Contaminated Site Management Guidelines No. 3 and 4, including the first version of the HAIL, draft updates to Guideline No. 5, contributions to the gasworks and sheep-dip guidelines, and review of landfill acceptance guidelines. Wrote the derivation methodology document and derived the Soil Contaminant Standards to support the NES regulations and assisted with drafting the regulations.

Advice to local authorities on redevelopment of contaminated land for residential purposes. Expert evidence at planning hearings and Environment Court. Facilitation of workshops on contaminated land.

Expert review of investigation reports, including reviews for government agencies, territorial local authorities, regional councils and public health authorities.

Principal contact for panel contracts with government agencies, including the Ministry for the Environment, Land Information New Zealand, and the Environmental Protection Authority, and past principal adviser to Public Health Services throughout the New Zealand on contaminated land and water matters.

Groundwater and surface water contamination assessments and investigation of groundwater for disposal of wastewater to land. Design and supervision of ground and surface water monitoring programmes, and ecological studies. Assessment of effects on surface water bodies.

Design of secure containment for hazardous wastes, landfill design, peer review of landfill design and operation.

Audit of remediation projects, including audit of monitoring of ground and surface water quality, and effects on the aquatic ecology.

Environmental risk assessment, including development of site-specific acceptance criteria for sites contaminated with wastes and chemical spills. Environmental auditing of industrial sites.

Investigation drilling, groundwater resource evaluation and design of groundwater supply. Investigation and design of construction dewatering systems.

Management of tunnel and dam construction, including rock excavation, earthworks, dewatering, concrete construction, grouting, drainage drilling, and steel fabrication. Management of soil and concrete laboratories.