Ecological water and wastewater engineering

Irrigation of Treated Domestic Wastewater

Duvauchelle

Preliminary Report

Evaluation of Site Options

For Christchurch City Council

by

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Contents

1.0 ACRONYMS

DPR: deep percolation rate
IFE: Irrigation field envelope.
wwtp: wastewater treatment plant

2.0 REPORT STATUS

This options assessment is a preliminary theoretical assessment with a purpose to inform further discussion, consultation, research and analysis. It does not commit the Christchurch City Council or land owners to any conclusions, recommendations or other outputs of this report.

3.0 BACKROUND

The ecoEng preliminary engineering report 19 April 2010 presented an assessment of the land irrigation requirements for the effluent from the Duvauchelle wastewater treatment plant.

The same report summarised the two most common methods for applying treated effluent into land; subsurface drip irrigation and surface sprinkler irrigation. Refer to Table 1.

Table 1. Comparison of drip and sprinkler irrigation

Subsurface and drip irrigation	• High cost (about twice the sprinkler option. • More even subsurface moisture distribution – if well designed. • Higher irrigation efficiency. • Normally higher yields. • Highest level of health protection – no aerosol and odour risks. • Almost all crops can be grown. • Can interfere with cultivation, replanting and harvesting. • Root penetration may be a problem.
Sprinkler irrigation	• Normally lower capital cost compared to drip irrigation. • Medium irrigation efficiency. • Lower level of health protection. • Crops may suffer leaf damage. • Can interfere with cultivation. • Can be affected by wind causing distorted distribution patterns of the wastewater and aerosol drift.

The type of irrigation technology and layout chosen will depend on the following factors;

- Landuse.
- Topography.
- Ecological and public health risks to mitigate.
- Local management capacity.
- Capital and operating costs and availability of technologies.

- Climate and microclimate

To achieve successful land application of wastewater the DSIR Guidelines[1] list the flowing key considerations:

- *Suitable soils.*
- *Suitable topography and hydrological conditions.*
- *Suitable climate.*
- *Efficient system design.*
- *Effective site preparation.*
- *Good management.*

In the case of the Duvauchelle sites we would add to this list the following:

- Landowner and community acceptance.
- Tangata Whenua acceptance.
- Consentable (RMA, Public Health Act, Building Act).
- Economically and ecologically sustainable.
- Technically feasible.
- Land stability and other geotechnical risks
- Maintainable and serviceable using local capacity.
- Appropriate monitoring.

The quantity of wastewater to be irrigated is based on 3 years (2007 to 2009) of flow data, the average and maximum monthly wastewater volume from the wastewater treatment plant were derived as in **Table 2.**

Table 2. Wastewater flows from the Duvauchelle WWTP

	Ave. daily flows for each month in m^3	
	Ave	Max
January	87.8	90.7
February	62.4	63.3
March	62.5	66.9
April	66.2	69.5
May	63.5	84.5
June	66.6	75.5
July	84.4	114.4
August	83.8	119.4
September	57.3	61.8
October	69.8	79.0
November	64.1	67.6
December	72.2	80.0

[1] DSIR 1976, Interim Guide for Land Application of Treated Sewage Effluent, Chemistry Division, NZ Department of Scientific and Industrial Research. Information Series No.114.

Using daily average flow for maximum monthly flow values in Table 2, a daily soil water model was used to model soil moisture deficit, saturation levels and nutrient application rates, to determine both land area requirements and storage requirements. This model allowed the setting of site specific soil-water-plant rules and calculates the land area required and balancing storage required for the given wastewater volumes delivered to the site.

The model was used to determine the optimum required irrigation area and pre-irrigation storage volumes. Irrigation for each day, over the 49 yrs of daily rainfall (RF) and evapotranspiration (ET) data, was permitted provided soil moisture content in the root zone (600mm depth) was less than the 92% saturation level [2].

The irrigated wastewater characteristics assumed were;

Biochemical oxygen demand, BOD_5	<20 gm/m^3
Suspended solids (SS)	<20 gm/m^3
Total nitrogen (TN)	<35 gm/m^3
Total phosphorus (TP)	<8 gm/m^3

The details of this modelling are presented in the ecoEng report 19th April 2010. The key outputs from this modelling exercise were:

- Land area required: 6ha
- Storage volume required: 3770 m^3
- Over flow days (from storage) no more than 10/yr
- Total nitrogen, TN, loading < 173 kg/ha.yr
- Total phosphorus loading TP loading <40kg/ha.yr

The above model assumed an average daily deep percolation rate (DPR) (soakage below the root zone) of 5mm/day.

3.1 Model sensitivity

A storage volume of 10,000 m^3 would achieve zero overflow days for the 49yrs modelled (all other input data unchanged).

Average over flow days/yr (with storage volume of 3770m^3) for different values for the DPR are given in **Table 3**.

Table 3. Sensitivity to DPR

DPR mm/day	Average overflow days/yr
4	32
5	10
6	4
7	2
8	1

[2] Recommended in, NZ Land Treatment Collective. 2000

Model Limitations

- Using average daily flows for the maximum month is likely to be conservative as it is unlikely that any one year would profile maximum monthly flows .
- The modelling did not allow for any projected growth within the Duvauchelle catchment. However the modelling was done on maximum monthly flows as noted above.
- The model is sensitive to assigned DPR values.

The ecoEng report, 19 April 2010, presented an assessment of the Duvauchelle's golf course and a possible site for the irrigation of the treated wastewater.

This report reassesses the Duvauchelle's golf course along with four other possible sites.

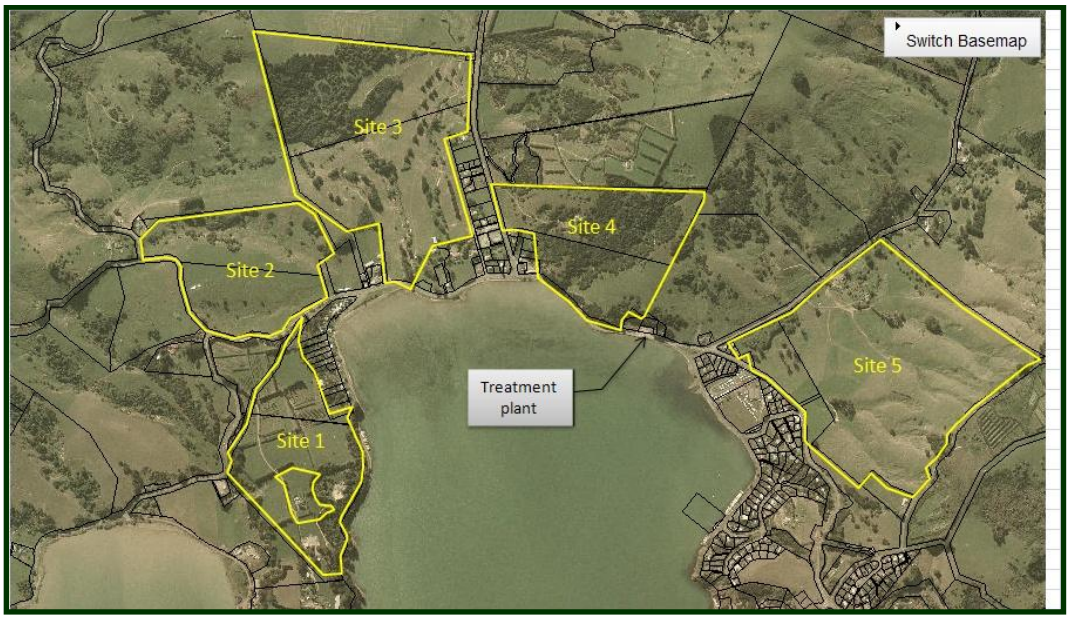
4.0 LOCATION OF SITES ASSESSED

The five sites assessed are illustrated in **Figure 1**. Refer to **Table 4** for details of these sites

Table 4. Site details

	Owner	Legal Description and area
Site 1	Neil Kay	Lot 5 DP 431346, 35.4 ha
Site 2	Mark Shadbolt	Pt RS571, 8.6 ha and Pt Lot 8 DP 1887, 11.7 ha.
Site 3	CCC	Pt Lot 14 DP1887, 21.9 ha and Lot 13 DP1887, 20.5 ha.
Site 4	A&E Foley	Pt Lot 3 DP 5105, 8.5ha and Lot 18 DP3473, 12.86 ha.
Site 5	T & S Craw	Pt Lot 3 DP4974, 40.7 ha and Pt Lot 4 DP4974, 4.7 ha.

Figure 1. Sites assessed



5.0 SITE EVALUATION

5.1 Site 1

The location of Site 1 and the layout of the IFE is shown in **Figure 2**. For details of the assessment of this site refer to **Table 5**.

Figure 2. Site 1

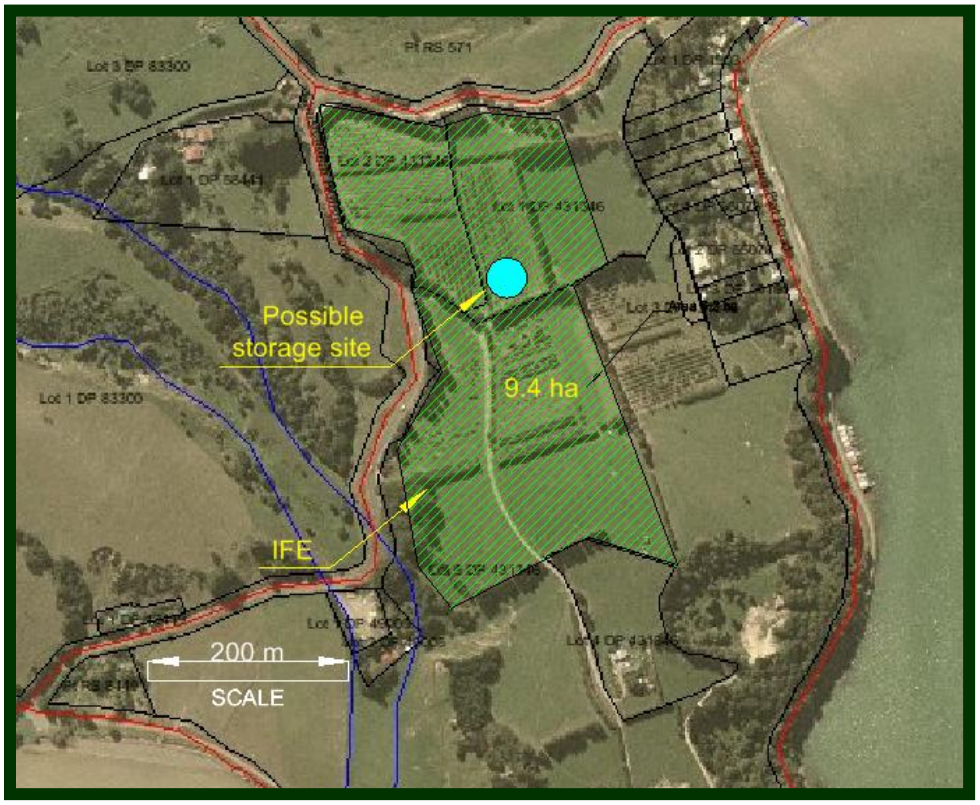


Table 5. Site 1 assessment

		Risk
Tenure	Property has just been sold. Change in ownership early 2013 (25 January).	To be confirmed
Technically available IFE[3] area	9.4 ha	Sufficient area. Low risk.
Land-use	Grazing and horticulture	N/A
Surface water bodies	Low risk to surface water bodies	Low
Drainage to harbour	Natural surface drainage will be to the harbour.	Moderate
Springs	Nil	N/A
Wells	Nil	N/A
Community water supply protection	Nil	N/A
Ground water	There are no groundwater resource exploited on this or nearby properties..	Low
Slope	Slope for selected area ranges from 0 – 15^{o}.	Low to moderate
Aerosol drift	Most of the site has good tree shelter	Moderate to low
Silent file	This is a silent file area.	Consultation with Iwi required.
Storage	Suitable site available. Height above the wwtp is about 45m.	Low risk
Distance from wwtp	1700m	N/A
Power	Readily available.	N/A
Risk to neighbours and public	There is a private residence within about 90m of the southern boundary of the IFE. The village is relatively close to the site - 70m to the east of the IFE and down-slope. Northern section close to main road.	Moderate
Visual impact	Established trees and shelter belts provide effective visual barriers.	Low

[3] Technically available IFE means that there was no initial land owner resistance, that the slopes and access are considered acceptable and set backs from surface water bodies and wells are acceptable.

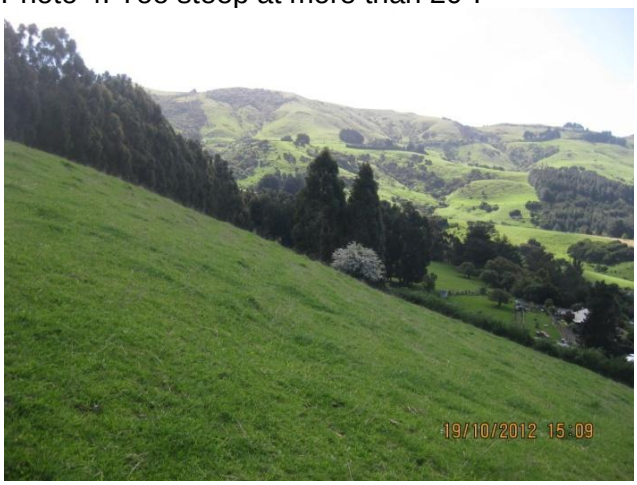
Figure 3. Photos

Photo 1. Flat and sheltered site

Photo 2. Possible storage site. 6 degree slope towards village

Photo 3. Steeper west facing site 10° to 15°

Photo 4. Too steep at more than 20°.



Key findings:

- Irrigable area of 6ha is available.
- There is a suitable storage site
- The site is close to the village and has one neighbour within 90m of the southern boundary of the IFE.
- The site is located within a silent file zone.

5.2 Site 2

The location of Site 2 and the layout of the IFE is shown in **Figure 4**. For details of the assessment of this site refer to **Table 6.**

Figure 4. Site 2

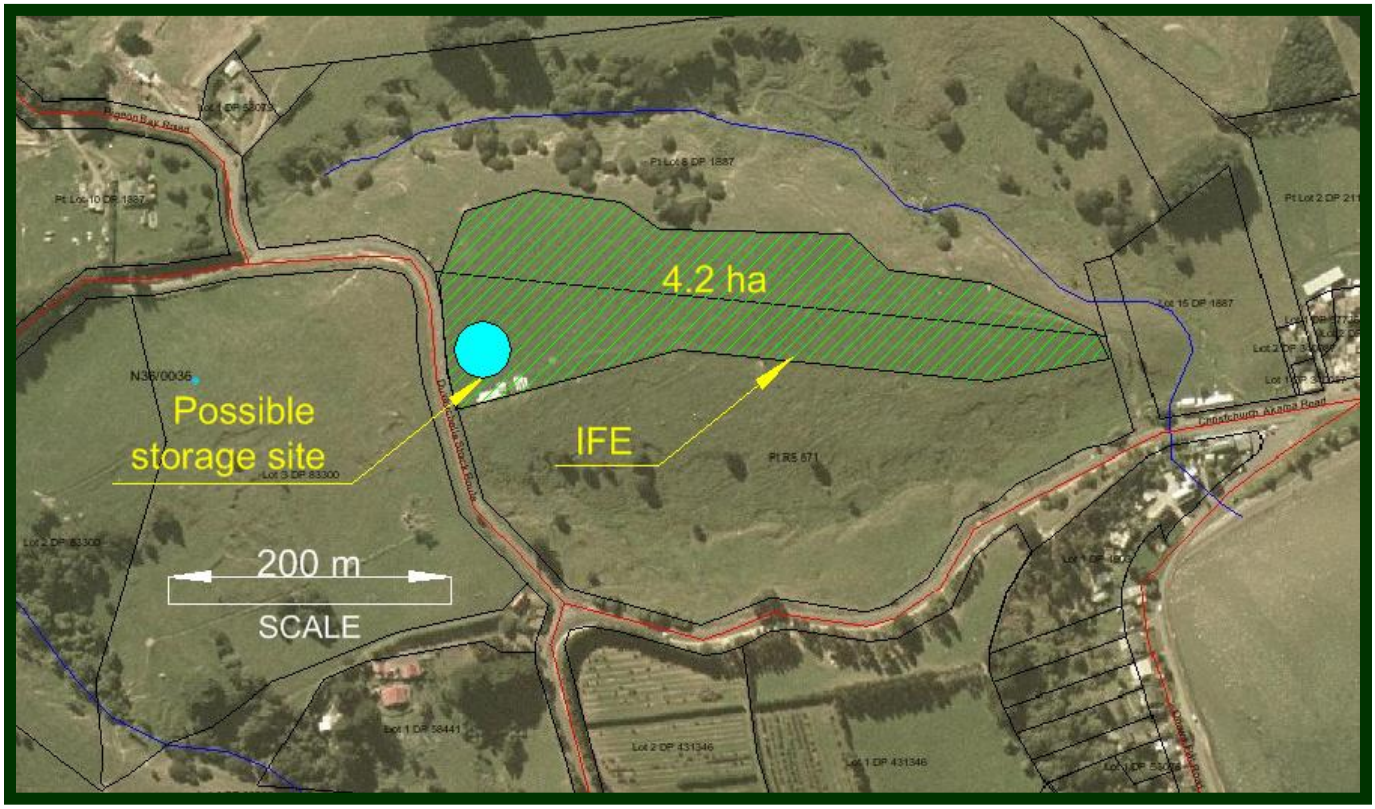


Table 6. Site 2 assessment

		Risk
Tenure	In private ownership	Property owner cooperative.
Technically available IFE area	4.2 ha	Insufficient area on its own. Risk high.
Land-use	Grazing	N/A
Surface water bodies.	No obvious surface water-bodies at risk	Low
Drainage to harbour	Surface drainage to gullies that feed directly to the harbour	Moderate
Springs	Nil	N/A
Wells	Nil	N/A
Community water supply protection	Nil	N/A
Ground water	Low risk.	Low
Slope	Slope for selected area ranges from 12^o – 15^o.	Moderate
Aerosol drift	The site is exposed with no existing shelter	High
Silent file	This is a silent file area.	Consultation with iwi required.
Storage	Site for storage has significant slope (12^o) and is very visible to the public. The site is about 75m above the wwtp.	Moderate to high risk
Distance from wwtp	1600m	N/A
Power	Readily available.	N/A
Risk to neighbours and public	The site is very visible to the public (see photos 5 and 6). There are no residence close to the boundary of the IFE.	Moderate to high
Visual impact	As noted above the site is very visible to the public.	High

Figure 5. Photos

Photo 5. Site 2 from the village. Note steeper gulley on the left.	Photo 6. View down the steeper gulley; unsuitable for irrigation.
	

Key findings:

- Irrigable area of only 4.2ha is available. At least 6 ha is required.
- Storage site is relatively steep.
- The site is very visible to the public.
- The site is located within a silent file zone.

5.3 Site 3

The location of Site 3 and the layout of the IFE is shown in **Figure 6**. For details of the assessment of this site refer to **Table 7.**

Figure 6 shows 2 IFE zones:

- Primary IFE zone; the preferred irrigation areas within established plantations. Lower pressure sprinklers would be safe on these area. The total area for primary IFE is only about 3 ha.
- The secondary IFE area (total area 10ha) is the golf course playing area. This area is irrigable, however sub-surface drip irrigation may be considered more suitable and safer.

Figure 6. Site 3

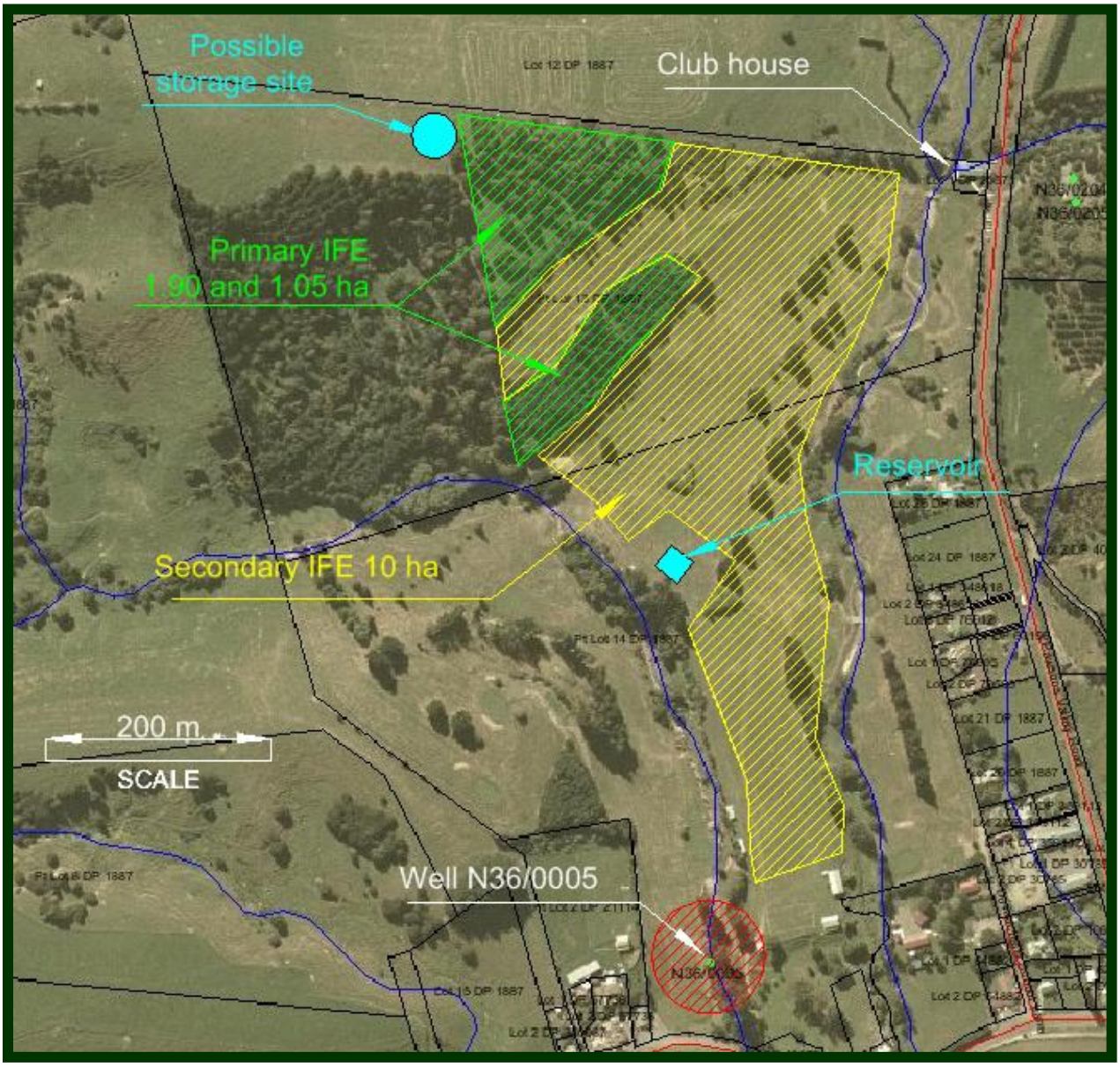


Table 7. Site 3 assessment

		Risk
Tenure	Council ownership	Agreement with Golf club would be required.
Technically available IFE area	Primary IFE 2.95 ha Secondary IFE 10 ha	Insufficient primary IFE area. Would need to use some of the secondary IFE area. The latter is likely to be higher public health risk.
Land-use	Golf club.	Low
Surface water bodies.	Two streams run through the property.	Moderate
Drainage to harbour	Pawson Stream drains to the harbour	Moderate
Springs	Nil	N/A
Wells	One well, N36/0005 is within the property boundary. This well is not currently being used. A 50m setback has been designated for IFE. (**Fig 6**)	Low
Community water supply protection	Nil	N/A
Ground water	On the lower flats risk to ground water will be higher	Low
Slope	Slope for selected area ranges from 12^{o} – 15^{o}.	Moderate
Aerosol drift	Primary IFE well sheltered Secondary IFE more exposed and risk to golfers.	Primary IFE – low Secondary IFE - high
Silent file	The primary and secondary IFE areas are outside the silent file zone	Consultation with iwi recommended.
Storage	There is a suitable site for a storage facility (See **Figure 6** and Photo 10). Height above wwtp is about 100m.	Low
Distance from wwtp	1800m	N/A
Power	The storage site is remote from a power supply.	N/A
Risk to neighbours and public	The primary IFE is some distance from the general public (although accessible to golfers) and neighbouring residential areas. The Secondary IFE does back on to neighbouring properries..	Variable
Visual impact	The primary IFE areas are well disguised and not visible to the public. Secondary IFE is visible to the public.	Low

Figure 7. Photos

Photo 7. View south down golf course

Photo 8. Top plantation area; open and accessible. Acceptable slope.

Photo 9. Lower plantation area; more dense planting. Acceptable slope.

Photo 10. Potential storage site	Photo 11 Main water course, Pawsons Stream.
	

Key findings:

- The land is owned by the City Council
- Total irrigable area of about 13ha is available,
- 100m lift to the storage site.
- Storage site relatively flat, well disguised and remote
- Potential risk to golfers
- The site is located outside the silent file zone.

5.4 Site 4

The location of Site 4 and the layout of the IFE is shown in **Figure 8**. For details of the assessment of this site refer to **Table 8.**

Figure 8. Site 4

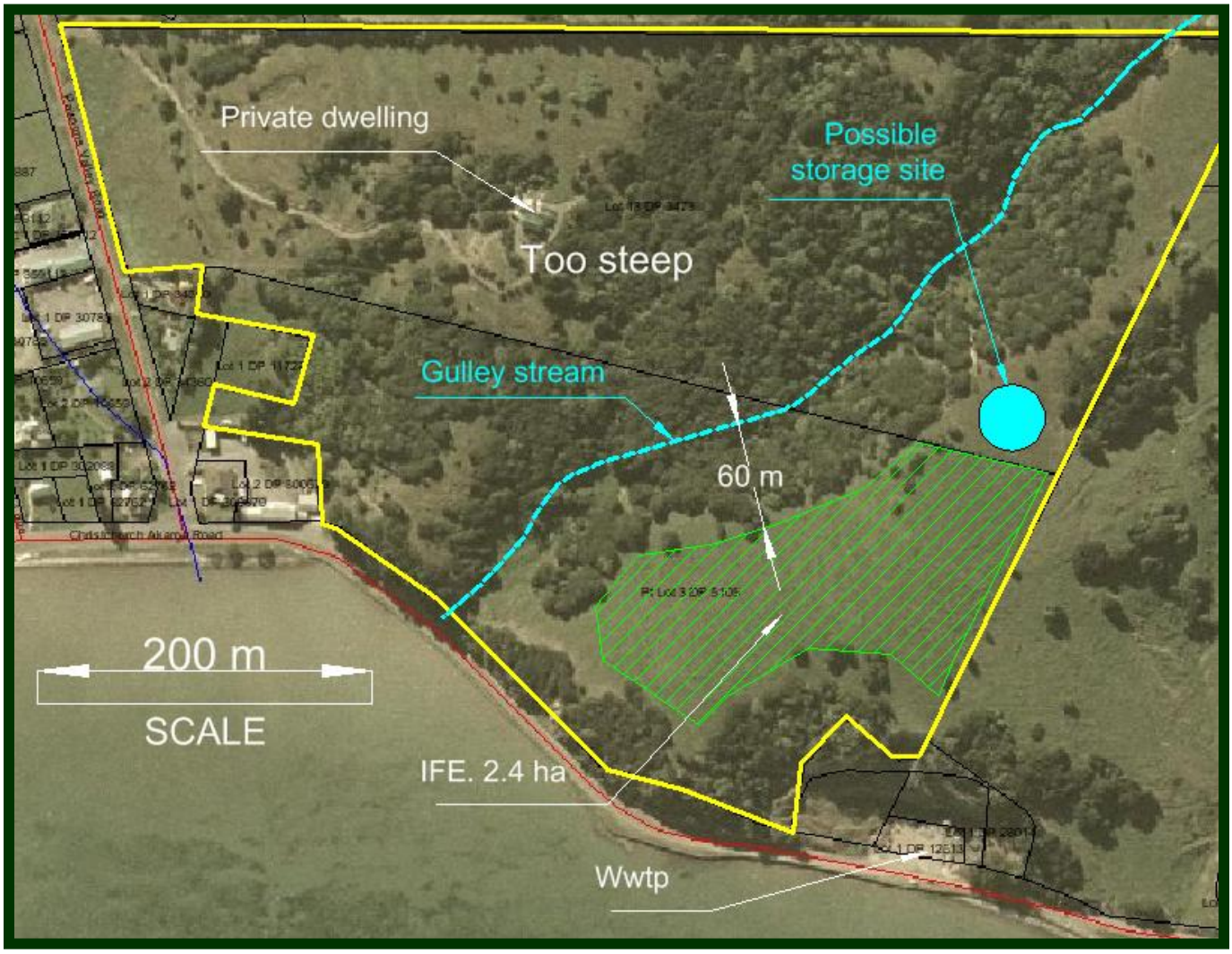


Table 8. Site 4 assessment

		Risk
Tenure	Private ownership	Property owner cooperative
Technically available IFE area	2.4 ha	Insufficient available area on its own.
Land-use	Scrub and grazing	N/A
Surface water bodies.	Steam to the NW of the IFE.	Moderate
Drainage to harbour	Gully stream drain directly to the harbour	Moderate
Springs	Nil	N/A
Wells	Nil	N/A
Community water supply protection	Nil	N/A

Ground water	No groundwater issues	Low
Slope	Slope for selected area ranges from 13^{o} – 16^{o}.	Moderate
Aerosol drift	Site is exposed but remote from neighbours and the public	Low
Silent file	The site is within a silent file area.	Consultation with iwi required.
Storage	There is a sloping (8^{o}) site for a storage facility (See **Figure 6** and Photo 10). Height above wwtp is about 97m.	Moderate to high risk
Distance from wwtp	350m	N/A
Power	Power is available on site	N/A
Risk to neighbours and public	The proposed IFE is some distance away from nearby dwellings. The closest dwelling is about 234 m northwest and is separated by scrub and trees.	Low
Visual impact	The IFE site is visible from the main road.	Low

Figure 9. Photos

Photo 12. Site 4 IFE from road

Photo 13. Site 4, Typical slope of IFE – approx 13^{o}

Photo 14. View down Site 4 IFE

Photo 15. Storage site

Photo 16. View looking up the gully stream

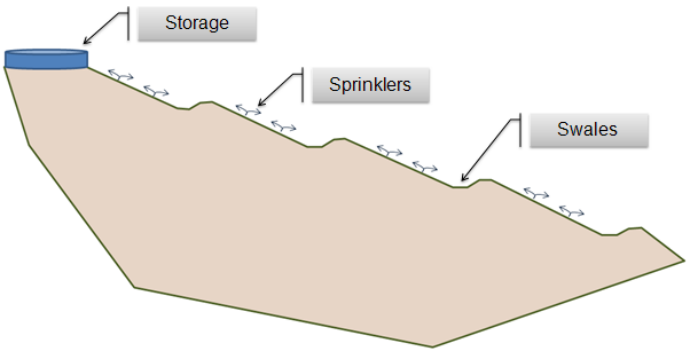
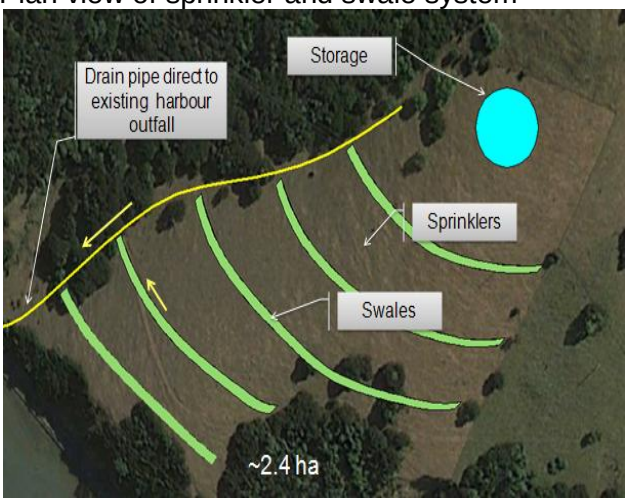
Photo 17. View down gulley stream to road and harbour.

One of the options for this smaller site might be to use this area to manage overflows. The site is close to the treatment plant and to the existing pipe discharge to the Harbour.

Several rows of overhead sprinklers could be installed on the contour down the relatively even sloping face . The slope could be excavate to form a series of contour swales which would collect any surface flow from the sprinklers and convey this to a common pipeline that runs down the end of the swales and eventually to the existing pipeline to the harbour (Refer to **Figure 10**).

This site would be used at times when the main irrigation area is not receptive to irrigation because of saturated soil conditions. Wastewater would receive additional treatment and filtering on the irrigated slope and within the swales and would be expected that by the time it had reached the harbour been

Figure 10. Photos

Cross section of sprinkler and swale system	Plan view of sprinkler and swale system
	

Key findings:

- Total irrigable area is too small at about 2.4 ha.
- Storage site has a significant slope.
- Potential risk to surface stream.
- The site is located within a silent file area.
- Potential as a standby site for over load events.

5.5 Site 5

The location of Site 5 and the layout of the IFE is shown in **Figure 11**. For details of the assessment of this site refer to **Table 9.**

Figure 11. Site 5

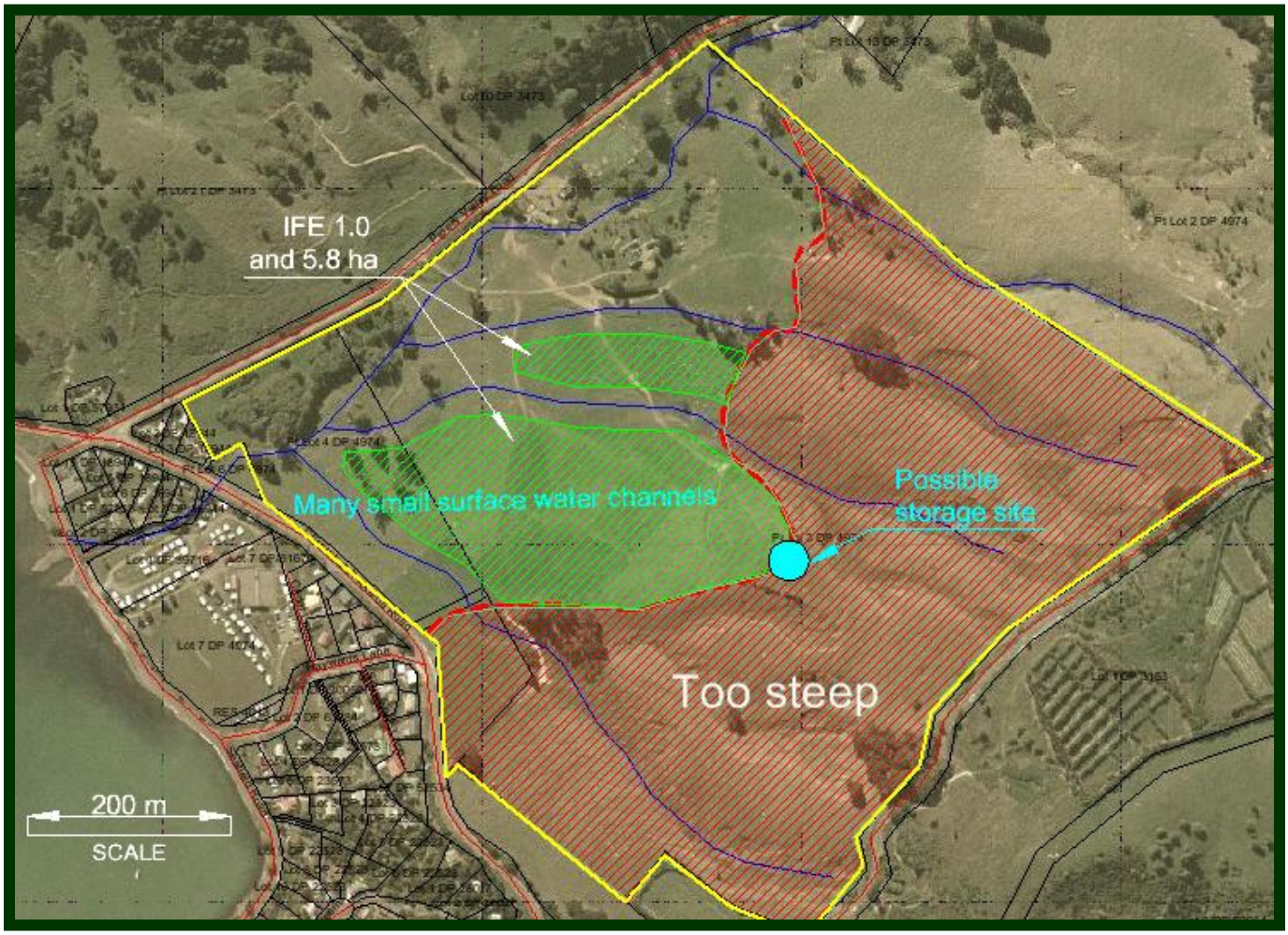


Table 9. Site 5 assessment

		Risk
Tenure	Private ownership	Property owner cooperative
Technically available IFE area	6.8 ha	Sufficient land area. Risk low.
Land-use	Grazing	N/A
Surface water bodies.	Many small and shallow surface water courses on this site.	High

Drainage to harbour	Drainage from the IFE will be direct to Pipers Stream which drains directly into the harbour.	High
Springs	Nil	N/A
Wells	Nil	N/A
Community water supply protection	Nil	N/A
Ground water	Groundwater is likely to be high at this site.	Moderate to high
Slope	Slope for selected area ranges from 5^{o} – 15^{o}.	Moderate to low
Aerosol drift	Site is exposed and lower area is close to the neighbours and camping ground on the south east boundary.	Moderate to high
Silent file	The lower area of the site is within the silent file area while most of the property is outside the silent file area.	Consultation with iwi required.
Storage	The storage would need to be benched into the upper slopes. No flat area is available. (See **Figure 10**). Height above wwtp is about 70 m.	Moderate to high risk
Distance from wwtp	About 880m	N/A
Power	Power supply is available.	N/A
Risk to neighbours and public	The site is very close to the camping ground.	Moderate to high
Visual impact	The site is very visible.	High

Figure 12. Photos

Photo 18. Site 5 sloping towards Pipers Stream (Photo 21) and camping ground

Photo 19. One of several shallow surface drains within the IFE.

Photo 20. Surface water following recent rain. (Photo taken 19 October 2012)

Photo 21. Pipers Stream

Photo 22. Steeper slopes towards the southeast boundary.

Key findings:

- Total irrigable area of about 5.8ha is available, which is insufficient on its own.
- Site has many surface drains feeding directly to Pipers Stream.
- Storage site and IFE very visible.
- The site is on the boundary of a silent file area.

5.6 Soils

The soils have not been evaluated in detail on each site.

The soils in this area are Pawson soils – a silt loam strongly leached, weakly gleyed, weakly gammate, palli-fulvic and fulvic -palli soils from moderately argillised loess from schist and greywacke. For these

soil types we can anticipate low hydraulic conductivity and therefore low infiltration rates. Application rates and application depths will need to be correspondingly low.

All 5 sites are expected to have similar soil drainage limitations.

A more detailed soil profiles assessment is recommended at the time a preferred site or sites are selected.

5.7 Slope stability

A detailed geotechnical stability study was not carried out on the sites. There were no obvious indication of mass earth movement or instability on any of the IFE areas selected. However ecoEng does recommend a more detailed geotechnical assessment be carried out at the time a preferred site or sites are selected.

6.0 EFFLUENT STANDARDS FOR GOLF COURSE IRRIGATION

A number of golf courses are irrigated with treated wastewater in Australia. As an example of effluent standards, the Queensland government (EPA) produced guidelines in 2005 for the recycling of treated wastewater; refer to Queensland Water Recycling Guidelines.

Their recommendations are that for above ground open space irrigation, uncontrolled access, Class A effluent standards is required. For controlled access or subsurface irrigation Class C. Class A and Class C standards are presented in the following table from the Queensland Water Recycling Guidelines.

Class	*E. coli* (median) cfu/100mL[2]	BOD5 mg/L median	Turbidity NTU 95% ile (max.)	SS, mg/L median	TDS, mg/L or EC, µS/cm medians TDS / EC[3]	pH
A	< 10	20	2 (5)[4]	5	1000/1600	6-8.5
B	< 100	20	—	30	1000/1600	6-8.5
C	< 1000	20	—	30	1000/1600	6-8.5
D	< 10,000	—	—	—	1000/1600	6-8.5

Footnotes:

1. *Use of any of these classes of recycled water should involve development and implementation of a Recycled Water Management Plan incorporating risk management. The location of the sampling point for these parameters will depend on the outcome of the Recycled Water Management Plan (see Chapter 4 of these guidelines).*
2. *As these values are medians, for each of these guideline values a response value should be set (e.g. 50% above the guideline value). If the response value is exceeded, another sample should be immediately taken. If this exceeds the response value again, the supply of recycled water should be suspended, and the non-conformance and corrective action process implemented, with supply not being re-established until conforming product can be guaranteed.*

3. *For sustainable irrigation, salinity should be kept as low as possible. For example, if TDS >1000 mg/L or EC >1600 µS/cm, a salinity reduction program should be implemented. However, there may be some uses where salinity reduction is not required, or where other salinity management options are more practical. This should be determined during the risk assessment.*
4. *Turbidity would generally be measured before the disinfection point at the treatment plant as this is the point at which low turbidity is essential. Monitoring at the treatment plant should be continuous with an alarm activated at an NTU of 2, and automatic shut-off of supply at an NTU of 5. If disinfection of Class A recycled water is achieved partly through processes that are less dependent on turbidity, an indicator other than turbidity should be used. For example, extended lagooning would use detention time in the storage as the critical limit (typically 40 days), rather than turbidity. Ozonation may use an oxidation-reduction potential (ORP) sensor, with the critical limit (in millivolts) determined by the quality of the feed water.*

Full details are provided in the Guidlines freely downloadable from http://www.nrm.qld.gov.au/water/regulation/recycling/pdf/recycle_guidelines.pdf.

7.0 IMPACT OF CLIMATE CHANGE

There are two potential impacts resulting from climate change:

1. Change in rainfall and evapotranspiration patterns, thereby affecting the soil moisture modeling:
2. Sea level change.
3. Extreme events

7.1 Rainfall and evapotranspiration

A NIWA June 2011 report to the Ministry of Agriculture and Forestry (*Scenarios of Regional Drought under Climate Change*) predicted the Canterbury region (including Banks Peninsula) is likely to experience increased drought (about 10% increase in drought frequency) . This would in fact work in favour of a wastewater land application system. The soils would be drier and more receptive to the application of treated wastewater.

Ministry for the Environment May 2008 report, *Climate change effects and impacts assessment* predicts more extreme events, including rainfall. Percentage adjustments (increase) for specific extreme rainfall events varied from 3.5% to 8% (Table 5.2 on the MfE May 2008 report). The implications of more extreme rainfall events would be:

- Increased risk of ponding and surface runoff;
- Increased risk of slope erosion on the steeper slopes;
- Increased risk of flooding from swollen streams and rivers .

7.2 Sea level change

Ministry for the Environment May 2008 report indicated potential sea level changes of 18-59 cm. This would not impact on the land application sites, however it could increase the risk of sea surges and wave impact on Duvauchelle's wastewater treatment plant which is about 6m above mean sea level.

7.3 Extreme events

Even though lower annual average rainfalls are predicted as a consequence of climate change, it is also predicted that there will be more extreme events such as rainfall and snow events. Such events are likely to give rise to a higher risk of surface ponding (and increased risk of erosion on slopes) and

flooding. These factors would need to be taken into consideration in the design and the management of wastewater land location system.

8.0 CONSENTABILITY AND ECOSYSTEM EFFECTS

Application of wastewater onto and into land will require a Resource Consent to discharge under Section 15 of the Resource Management Act (RMA).

The relevant Canterbury Regional Council rules that apply to Section 15 are the Natural Resources Regional Plan (NRRP) and the proposed Land and Water Regional Plan (LWRP).

These rules identify a number potential risks. These include:

- Risk to groundwater and surface water;
- Risks to community water supplies;
- Risks to public health;
- Effects on air quality;
- Effects on cultural and historical values;
- Surface ponding, flooding and slope stability.

The ultimate site selection and design of the irrigation system will be required to take these and other factors into consideration.

9.0 CONCLUSIONS

- Increasing the storage to achieve zero discharge days may be considered an appropriate economic option.
- Sites 2 and 5 are likely to be considered unsuitable.
- Site 1 is currently changing ownership. Land owner co-operation is therefore unknown. However this site does have some favourable attributes.
- Site 3 is council land and could be a suitable site. The storage site is at a relatively high elevation and is the furtherest distance from the wwtp.
- Site 4 is small and relatively steep, however it may be used in conjunction with Site 3 as a suitable site for a low cost overflow site using a technique of contour irrigation to swales. This system would use low pressure overhead sprinkler irrigators (such as the K-line irrigation technology) with controlled runoff to contour swales which drain to a dedicated storm water drain with direct outlet to the harbour or the existing sewer pipeline to the harbour. The requirement for this site to be used would be negated if a larger storage facility was preferred.
- Climate change is likely to work in favour of land application of treated wastewater.

10.0 RECOMMENDATIONS

Issues and questions requiring further consideration include:

a. What development and population growth projections are appropriate for Duvauchelle?
b. What frequency of storage overflow is acceptable?
c. Is overflow discharge to the harbour acceptable, perhaps using the existing sewer pipeline into the harbour?
d. Will tertiary treatment be required?
e. If a trail irrigation area is set up, the outcomes of this research should be used to the refine modelling of the full scale land application system.