Developing light sand pasture dunes into irrigated land

Is it feasible to re-contour poor-performing sand country into irrigated farmland from a bore well?

Kellogg Rural Leadership Course July 2015

Hamish Easton 2015

Executive Summary

The New Zealand government has set a goal of doubling the value of exports by 2025. In order to achieve this, the Irrigation Acceleration Fund (IAF) was allocated $35 million over five years to support the development of irrigation infrastructure.

Rangitikei local government had employed Catalyst Group an environmental management consulting company to conduct case studies on irrigated and non-irrigated properties to the determine potential of expanding irrigation. It would appear that central and regional governments are keen to develop more land under irrigation.

The aim of this project is to understand the formation of sand dunes in the lower west coast of the North Island and their stability. Secondly the project aimed to find out what support from Government has been provided for farmers to develop their land to irrigation? Lastly the project provides a case study on re-contouring land.

A range of interviews were conducted to explore the aims stated above. Dr Alastair Clement from Massey University was contacted to understand how local dune fields were formed and stable they are, and how they were unique. Hew Dalrymple a farmer near Bulls was interviewed to see how their current irrigation project was proceeding.

The lower North Island sand dune area has undergone massive transformation over the past 10,000 years and parts are still forming. Early Maori and European settlers have influenced this dune area more recently (past 1,000 years).

Developing these dunes would always be restricted by cost to develop. But it had been proven to be feasible to irrigate and produce increased returns from the land. Current regulation provides a reasonable framework for farmers to adhere to. More information from regional councils could improve the process to help estimate costs and barriers.

Contents

Acknowledgements

Firstly thanks Dr Alastair Clement at Massey University for providing me with great information regarding the Manawatu Sand Country.

I was fortunate to be able to spend over two hours with Hew Dalrymple looking over his farm near Bulls, gaining valuable insight into developing sand country to irrigation. Elton Mayo contributed information on seed recommendation.

Also thanks to Patrick, Anne and Desley for guidance throughout our Kellogg Rural Leadership course.

Lastly thanks to my wife Devon for her support during this project.

1. Introduction

The New Zealand Government has set a goal of doubling the value of exports by 2025. The Irrigation Acceleration Fund (IAF) was allocated $35 million over five years in the 2011 budget to support the development of irrigation infrastructure proposals in three areas:

- Regional rural water infrastructure
- Strategic water management studies
- Community irrigation schemes

As a result of this the Rangitikei Strategic Water Assessment Project was created and, funded by the Rangitikei District Council and MPI via the IAF. This has also since included Horizons Regional Council as partner to look at the potential of expanding irrigation on the lower North Island west coast sand dune fields.

A key task undertaken by the Catalyst Group was the development of case studies on irrigated and non-irrigated properties.

Sand dune formation on the Manawatu coast has taken place over the past 10,000 years. What is the ramification of human imposition on these dunes and should they have more protection?

If irrigation is possible - is it economically feasible to develop this land and what will the result look like? Consideration of regulatory process needs to be taken into account to ensure the best environmental outcome is possible.

2. Aims and Objectives

A key aim of this project was to see whether it was feasible to develop irrigation on sand dunes. Interviews were carried out to understand the sand dune field and, what support there is from central and local government to develop this land. The experiences of a local farmer and the issues they encountered is provided as a case study.

Figure 1: Recently contoured sand dune. H Easton October 2015

Figure 2: Sand movement from recently contoured sand dune. H Easton October 2015

3. Literature Review

3.1 Saudi Arabia irrigation

Irrigation is possible on any land and you would only need to look at Saudi Arabia to prove this. When viewed from space, pivot irrigation dots the landscape randomly, however these have been strategically placed over ancient river channels to depths of up to 1km. These are non-renewable sources accumulated over 2 million years. Saudi Arabia has since developed dams to trap seasonal floods to provide water in the future and desalination plants to provide fresh water to mitigate the depletion of ancient river channels. (Wikipedia, Saudi Arabia Irrigation)

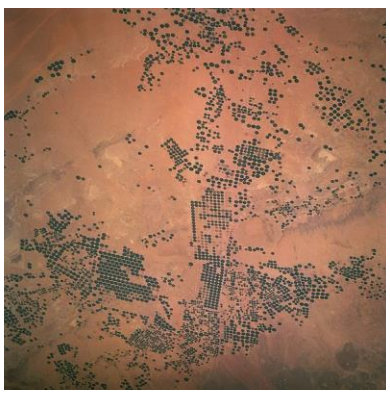

Figure 3: This picture is a view from space showing crop circles under irrigation in Saudi Arabia, Wikipedia. April 1997.

3.2 Manawatu sand country

The Manawatu sands are a variety of dunes, sand plains, peaty swamps and lakes near the coast of the lower North Island. It can be split into four dune building periods. The youngest being Waitarere (up to 100 years old), which are unconsolidated and border the coast; Foxton dark grey sand (500 – 2000 years) with a shallow top soil up to six inches and, prone to stock damage that can cause blowouts; the Foxton black sand (4000-6500 years). This dune field was developed over the past 6500 years. The dune field migrated over the floodplain and reached 16km inland where they consolidated. They are more consolidated such that up to 14 inches of top soil has developed. The subsoil is characterized by a brown colour and it is suitable for grazing. The dune field has a tendency to dry off through summer due to excessive drainage. The last dune building period (10000 – 15000 years) is the Koputoroa sandy loam which has the best soil structure and less chance of erosion due to wind.

Within the Foxton black sand and grey sand dune areas, you can find a mixture of soils as shown in the diagram below:

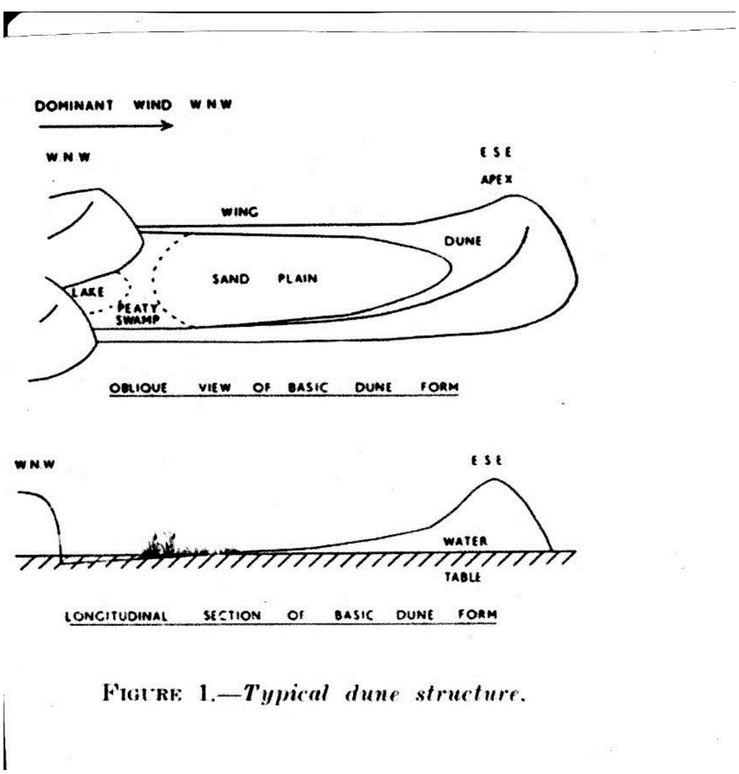

Figure 4: Typical sand dune structures, Cowie, 1957

Figure 4 shows black sands on the dunes, Awahou loamy sand on the higher sand plain followed by Carnavon black loamy sand in the lower parts, before Omanuka peaty loam in the peaty swamp. (Cowie, 1957)

3.3 Maori and European Influence

The last stage of dune phase has been in the past 1000 years. Due to the arrival of Maori and followed recently by Europeans the dunes were affected, causing the extinction of a range of fauna and vegetation through grazing, and cropping activities. From 1940 to 1990 however with the arrival of fertilizer and improved farming techniques the dune fields have been mostly stabilized by human intervention. (Heslop, P, 2001)

3.4 MPI Statement of Intent 2025

This Government has committed to a program (2013-2018) for looking at ways to increase primary industry exports. The goal is to double exports by 2025 which would also see the ratio of exports to GDP grow to 40%. Current programs of increasing irrigation will contribute to this i.e. the Irrigation Acceleration Fund (IAF). (Ministerial Statement of Responsibility: Statement of Intent 2013-2018)

3.5 Irrigation Acceleration Fund (IAF)

IAF was allocated $35 million in 2011 budget to fund three components that target delivery of rural water infrastructure:

1. Regional rural water infrastructure
2. Strategic water management studies
3. Community irrigation schemes

The IAF can cover half of a program cost. This has enabled Rangitikei District Council and Horizons Regional Council to fund a strategic water management study to investigate the potential of expanded areas of irrigation. (Irrigation Acceleration Fund – Summary of Project Progress, updated 28 July 2014)

3.6 Rangitikei Strategic Water Assessment Project

This is funded jointly by the Rangitikei District Council and Ministry for Primary Industries through IAF. This has since included Horizon Regional Council to partner looking at the potential of expanding irrigation on the west coast dune fields.

A key task undertaken by the Catalyst Group was the development of case studies on irrigated and non-irrigated properties. The Catalyst Group is an environmental management consultancy specializing in strategic thinking, policy and planning, land, water and biodiversity.

The project was to gather information on;

- Availability and certainty of water supply
- Efficiency of current water use

- Identification of areas of improvements for efficiency
- Costs, benefits, on-farm implications, and regulatory and environmental considerations around irrigation
- Alternative uses for irrigated land.

One of the conclusions found was that most farmers interviewed, felt that water efficiency was of low priority as there was plenty of water available and the cost of accessing was low. This is in contrast to Canterbury where efficiency had more emphasis due to the restriction and cost to secure water. Most interviewed felt that nutrient loss limits (Horizon Regional Councils One Plan) were likely to be a driver towards greater efficiency. (The Catalyst Group, August 2014).

3.7 Costs and Benefits of Irrigated Farm land

Has dairy farm land become overpriced? When valuing farmland do we aim to use a 'check method' - by using a cost or income approach? The cost approach includes getting water to a pivot and the pivot spraying water. Additional costs to consider could be re-contour of the land, capital fertilizer, regressing and consents. Whereas an income approach would consider the returns from irrigating different soil types (light sand, wet sands). Another consideration is the difference between average and top management regimes. (Iona McCarthy, 2011).

3.8 Estimating profitability of irrigation on NZ dairy farms

A calculator was developed to help dairy farmers with the return on investment with irrigation. Three modules are looked at:

1. Pasture production
2. Expenses associated with irrigation
3. Comparison of base farm (without irrigation) with irrigated farm

Three Manawatu dairy farms were used as an example on contrasting soil types. They are in three different climates: Himitangi (dry), Milson (average) and Shannon (wet). Although more grass was grown on the dry soil you would assume that the return would be better. However because you then have to increase the stocking rate, the costs associated dramatically rose as well. How this extra grass is utilized is as important as the extra grass production. If the existing herd grazes this grass the more profitable it becomes. (J. Howes, D. Horne, N. Shadbolt, 2014).

4 Methodology

This research project was undertaken to see if developing light sand country into irrigated farmland was viable. Research was conducted to understand how these sand dunes were formed and the impact of humans. Massey University departments were approached to gather information about the Manawatu sand dune field and any previous research in relation to irrigation on sand country.

The Dalrymple's were interviewed as a local case study to learn more about how they went about re-contouring sand dunes, the cost and any regulatory frameworks they encountered. Seed sale reps were consulted to learn more about what pasture/ cropping was feasible.

5 Discussion

5.1 Foxton sand dune area

These dunes were formed over the past 6,000 years and spread inland up to 16km from the coast. They are considered to be consolidated, but can be separated into two soils: Foxton dark grey has a shallow top soil of up to 6 inches and due to excessive drainage dries out very quickly with no rainfall (within week) in late spring early summer onwards. It can maintain pasture however can be damaged by stock which can expose sand to the prevailing winds to cause blowouts.

The next soil is black sand, which has up to 14 inches of topsoil. This like Dark Grey topsoil is excessively drained and prone to drying off in summer. It is however less likely to blowout with wind and is considered more consolidated. J.D Cowie stated ‘Fair pastures can be maintained on Foxton black sand but because of the excessive drainage they dry off in summer. Blowouts are not as numerous as on Foxton dark grey sand’ Cowie (1963).

Cowie also goes on to state ‘productivity of the soils is, however, largely dependent on the amount of soil moisture available during the growing season. Satisfactory pasture growth is only possible where the water table is within reach of the plant roots and any excessive lowering of this water table by drainage, although it may benefit some areas, will adversely affect other areas’ Cowie (1963).

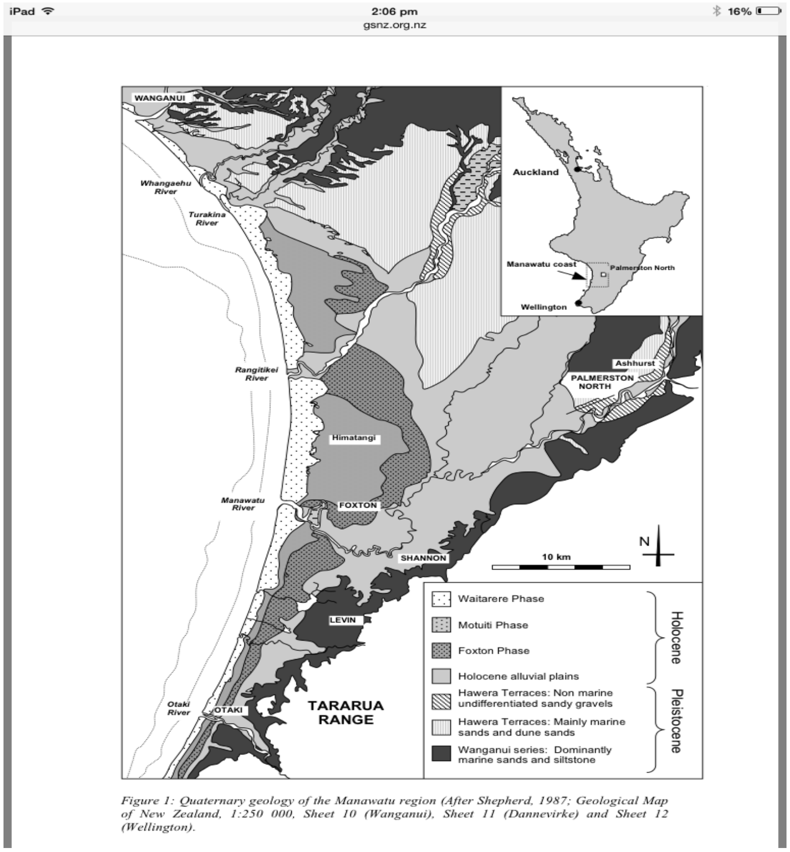

Figure 5 Manawatu Sand Country, Shepherd, 1987

This would suggest that the most important part of the dune to protect would be the top soil. If you are to disturb the dunes as early Maori and European settlers had - either by over grazing or horticulture and burn-offs, you could potentially break the shallow top soil exposing the raw sand to the prevailing winds. Once this sand is exposed it has the potential for blowouts. Regaining control and creating thin topsoil for vegetation and fauna to stabile the dune would have been very hard to do in the past. However since 1940 it has been proven that you can build top soil from farming it, or leave it to regenerate. The modern advent of irrigation would provide the missing component that Cowie had established - the only limiting factor would be water.

5.2 Current Rules, Regulations regarding Sand dunes

Obtained from the Horowhenua District Council website Horowhenua District Plan, Part C Rules: Section 19 Rural Zone http://www.horowhenua.govt.nz/Council/Council-Documents/District-Plan/Operative-District-Plan-2015/

The current rules apply for earthworks within the Foxton Dunefields:

19.6.12 Earthworks-Specific Landscape Domains
(a) Earthworks, other than cut for a building platform, on land that is not an Outstanding Natural Landscape and Feature, shall not exceed the following:

(iii) Foxton Dunefields Landscape Domain
- 3 metres (cut or fill) measured vertically
- Where earthworks exceed 3 metres (cut or fill) measured vertically, those earthworks shall not exceed 5 metres (cut or fill) measured vertically and shall not exceed a distance of 50 metres in continuous horizontal length.
- Where earthworks are to be undertaken on a dune, the vertical height of the dune, or any part of that dune, prior to the earthworks shall be no greater at any point than 10 metres from toe to summit.

Exception:
Earthworks provisions shall not apply to production forestry harvesting on a dune 10 metres in height or lower.
(b) All disturbed surfaces shall be revegetated within 6 months of the completion of the earthworks.
Note 1: When used in Rule 19.6.12, the term earthworks does not include Aggregate Extraction, activities such as cultivation and harvesting of crops, planting trees, removal of trees and horticultural root ripping where these activities do not reshape or recontour the land, digging post holes or drilling bores, digging offal pits, burials of dead stock and plant waste and installation of services, notwithstanding anything in the definition of earthworks to the contrary.
Note 2: Earthworks does not include gravel extraction and other works within the bed of a waterbody. This is managed by the Regional Council.

This basically means a sand dune from tip to toe up to 10 meters tall can have 3m removed and up to 5m for 50m long, anything above 10m will need consent. It is interesting to note the Rangitikei Council and Horizons Regional Council have no rules surrounding this but do require approval for earthworks. These dunes are natural features of the Manawatu coast line however have limited protection against their destruction. The only explanation I could have for this would be the prohibitive cost of re-contouring them completely. It is clear that to completely smooth a dune over 10m in height would never be economic or sustainable (due to the simple fact there wouldn't be enough top soil to smooth back over).

5.3 Case study Dalrymples, Bulls

This case study looks at one farmer who is undergoing a process of re-contouring sand country near Bulls and putting in irrigation infrastructure in order to improve the land. Hew Dalrymple was contacted as an excellent example of what could be achieved by spending time and resources to improve sand country. Having lived there his entire life he has seen numerous changes brought about from improving land.

I was fortunate to have Hew show me around their property, looking at past projects of re-contouring to allow irrigation pivots be set up, and their new venture with local iwi developing the former training flock house farm. It was clear from the outset that the Dalrymple's were clearly passionate about developing land under their guardianship.

5.4 The process of re-contouring dunes

The land had been re-contoured with the use of a mixture of machinery. A bulldozer was their primary form of removing top soil to work the dune beneath. Motor scrapers were used to move sand where the distance was prohibitive for pushing with the bulldozer or digging with diggers. In some instances up to 5 metre-long cuts had been made to lower dunes. Hew stated that it wasn't necessary to make big cuts to flatten dunes - it was more about making adjustments to the slope in order for the pivot to pass

over freely without the cross beams between pivot wheels being caught by the ground beneath. This helps to lower costs of earth moving as less sand is being shifted.
After the slope of the sand dune is contoured to the requirements for pivots, the topsoil is pushed back across evenly to ensure a seed bed is there for planting again. Hew also noted that keeping the site not completely smoothed out with levelers until right up to drilling of seed was required to keep the wind from blowing away soil. Before any earthworks commenced Horizons Regional Council were consulted for consent to alter the dune area.

5.5 Process of irrigation infrastructure

The bores are the hardest part to budget for, two reasons. Firstly you don’t know how deep you need to go until drilling starts. It all depends where they find sufficient water for your needs and gravel in order to extract it. At $1,000 per metre the best scenario would be at 50 meters rather than 300m depth. Secondly even if you have sufficient water at a shallower depth a water consultant is required by council to recommend that this will not impact water aquifers at that level. They may require a farmer go deeper to ensure no negative effects to shallow aquifers. This can add to your cost significantly and needs to be addressed carefully. Horizons Regional Council has information regarding this process. They require you fill out an application form before you can drill and construct a ground water bore, and fill out another application to take ground water.

All of Dalrymple’s property to be irrigated has been GPS mapped by Water Force Irrigation Company to work out the size and location of pivots to fit the land area. They have the job of working out getting sufficient water from the bore to the pivots, setting them up and power to drive them as well.

Hew Dalrymple also believed that over the time irrigation has increased in its use, the process of gaining consents and setting up has got easier - not harder to do. This gives him more confidence to continue developing land to its potential.

5.6 Cost of development

This was difficult to measure and even justify. The Dalrymple's had good technology in their machinery to measure the gradient of land, and work out how much needed to be moved. The cost of actually employing machinery to do the work was harder to work out. Hew estimated that on sand hills up to 10m high it could cost as high as $10,000/ha to re-contour. However when taking into account that some of the land was flat the average cost overall would be lower than $5000/ ha. Added to this is the cost of setting up irrigation estimated at a further $5000/ha. This seems a lot of money when only 100ha could potentially cost $1 million dollars.

Figure 6/7: Land recently deforested and flattened for pivots near Foxton, Hamish Easton, September 2015.

The only way to justify this would be to assume that the land was priced lower due to the poor production from it. Land in the Manawatu ranged from highly productive land growing 18 tonnes dry matter / ha at up to $50,000/ha, - to poorly productive land growing 6 tonne /ha up to $15,000/ha. Improving this land under irrigation to produce towards 16 tonne production would significantly increase the value of this land. In simple terms land valued at $15,000/ha when re-contoured and with irrigators set up at $10,000/ha would provide cheap land at $25,000 with the potential of year round production of up to 16 tonnes/ ha. This would exclude the running costs of around $400/ha annually to get water on (electricity, maintenance, fertiliser), and fixed costs $600/ha (interest and depreciation).

Figure 8: Sand blows before resewn into grass, Hamish Easton, 2015

This is a very simple workout of costs as actual costs will vary (eg, if development work is contracted out) and over time will rise due to inflation. It would be important to get more costs worked out with finer details to give a better indication, but for the purpose of this project it was to be a concept paper rather than a business proposal for banking purposes.

It was important to note that throughout the time spent with Hew that his passion for developing land to increase productivity was as important as the underlying figures for return. Although he believed that the return would be made back within five years, some areas probably would take longer and may not have been as profitable but made the property look great. He had an attachment to it, and you cannot place a value on this intrinsic value as urban population has to improving their house and section.

5.7 Pasture/crop establishment

A cover crop was recommended to ensure the prevailing wind doesn't cause loss of top soil. Any kind of grass was recommended as moisture would no longer be an issue. Hew has had good results with Bealey perennial ryegrass, which is tetraploid with excellent palatability and high yields. But the use of tall fescue has good results especially in a dairy system. Lucerne was another option due to its ability on dry soils to withstand drought. However the fact remains you are adding moisture to solve drought problems.

Figure 9, Cover crop on re-contoured dune, Hamish Easton, 2015

5.8 Water efficiency

Hew had invested in pivots with variable rate technology, which means he could alter the rate of water for different areas within the pivot circle. They had probes measuring soil moisture which helped identify areas that needed more or less water put on. He estimated that heavy flats required only 3mm of water per day compared to poor soil with less top soil and less water holding capacity needing 5mm per day. Compared to other methods of irrigation, pivots offer the most options for water efficiency use. Other irrigation such as K-Lines are cheaper to install but because they are moved less they tend to put more water on at once. This is not as ideal for poor soils with low water holding capacity. Pivots allow small amounts (up to 10mm) to be applied so that plants don't get under stress from longer periods before water is applied again (every day for pivots and ten day rotations for K-Lines). This would be important for sand soils as they are excessively drained and have poor water holding capacity.

5.9 Nutrient loading

Managing nutrient loading will be a concern as it will increase potentially. However pivots have the best result as you can put smaller amounts on more frequent than any other irrigation system. This can range from as low as 4mm for pivots, and up to 100mm for border dyke systems. The OVERSEER ® model is greatly affected by the water holding capacity of a particular soil. Sand has a poor water holding capacity than most other soils. This means that your leaching footprint could increase and depending on council regulations - you may not comply. It would be best to use consultants to work out if this is a problem.

5.10 Building top soil

Under present systems of dryland grazing the land produces up to 6 tonnes of dry matter. Due to this, grazing is limited throughout the year, thus less stock effluent is applied. Part of the process of building top soil requires a system in which organic matter is applied and decomposed. This would include plants as well and fertilizer to increase growth. Hew estimates that 1cm each year is added under cattle grazing; the more grazed the better this system works. This may sound not much but in 10 years 4 inches is created. Again, without the necessary moisture the system is slower, as less production of dry matter is created.

5.11 Return on investment

This is particularly hard to gauge for reasons outlined previously. Although it most probably will add value to the land when sold, the immediate returns were harder to determine. This is because of the fact that increasing the stocking rate will increase costs such as in maintenance feed per cow. Other factors that need to be considered are good vs average management. The best scenario seems that having the existing stock utilize extra feed grown. This may mean that existing supplementation is cut back to utilise this feed. I would suggest a balance of both will take place, but it is clear the more existing stock utilise extra feed, the more profitable it will be. This would have to ensure feed management is improved otherwise the feed will be wasted.

5.12 Capital costs of irrigation per/ ha setup

	$/ ha
Pump shed	200
Pipelines, electrical cable	1000
Pivot installed, pumps	2300
Bore	500-2000
Total cost of irrigation	**$4000-5500**

5.13 Development costs

Re-contouring sand dunes, fertilizer, tree removal, fencing, bridges, regressing.	**$5000/ha**

Development and setup approximately **$9000-10500**/ha @ 5% interest

= **$450-525**/ha/year

This would exclude depreciation on fixed assets (pivot, electrics, pipes, pumps, etc) of approximately **$100**/ha based on a 30 year life.

Another consideration is tax. If re-contouring could be expensed rather than capitalized this would bring the cost down significantly, I have only considered all re-contouring as capital although some expenses such as installation and regrassing would fall easily into expenses.

5.14 Budget

	$/ha
Income $6 / milk solid	
Existing production 6t grass @14kgsDM / 1kgs milk-solid (ms)	$2,571
Milk extra 10t grass @14kgsDM /1 kg ms	$4,285
Total	**$6,856**

Costs	
Running costs power, maintenance	$400
Farm working expenses @$3.5 / ms	$4,000
Interest, Depreciation	$600
Total	**$5000**

This could potentially leave a surplus of $1,856 / ha, however this could be plus or minus $1000 / ha due to the many variables outlined throughout this project. In comparison if land left to original condition producing 6 tonne of feed a surplus of around $1000/ha would still be possible as shown in calculation below:

6000 kgs Dry matter divided by 14kgs/ms

=428 milksolids @ $6 =$2,571/ha

Minus farm working costs 428 times $3.50 ms = $1,498

=$1,073/ha profit

6 Conclusion

Central and local governments seem keen for irrigation to be developed in New Zealand. They have invested significant funds into the Irrigation Acceleration Fund to provide assistance towards irrigation infrastructure, studies and schemes. The stated goal of doubling the value of exports will need projects like this to help achieve that goal.

Sand dunes in the Manawatu have been undergoing transformation for long periods of time at different stages; they are initially formed by excess sand at seaside, and blown inland from the prevailing westerly wind. Early Maori and European settlers had a dramatic impact on destabilizing these dunes by burn-offs of fauna and vegetation, for grazing and horticulture purposes. Over time these dunes will stabilize if left to regenerate. Since 1940 improvements in farming and technology have led to sand dunes becoming more stabilized with the amount of top soil increased. The limiting factor will always be available moisture. If irrigation is possible this land dramatically increases its potential.

Re-contouring of sand dunes is an expensive process, but if managed correctly by removing existing top soil to re-contour sand beneath, the land owner will reap the benefits immediately. The less sand moved the less expensive this process is. Protecting existing top soil has massive benefits. Keeping costs to below $5,000/ha on average for earth works is probably the benchmark to keep to. An important factor to keep in mind is the existing price paid for land as it may be easier to buy more land.

Nutrient loading needs to be addressed using the OVERSEER ® model. If you fall outside rules of the One Plan from Horizons then there would be no point in continuing. Consultants trained in the use of this model can quickly determine this.

The rate of return on investment is tricky to prove, as various outcomes are common. Whether extra grass is utilized by existing stock and whether there is an improvement in management are vital for consideration. This can materially change the outcome for any irrigation project. It appears that removing supplement would be a good place to start to ensure any increase in stocking rate would be mitigated. Any improvements in the management of feed supply will lead to better results so should definitely be looked at. DairyNZ has great tools for this.

7 Recommendations

Any project which would need major earthworks for irrigation needs to be thoroughly thought out and researched. The following are ideas I would recommend.

- Breaking down the process into steps is an easy place to start. A follow up piece of work could be to provide a checklist of steps, and where to seek advice.
- Updates of actual costs will need to be added to the checklist.
- Local government could potentially hold information evenings to provide advice on the process and consents needed to be obtained.
- Farmers should seek advice from other farmers who have completed or are underway in the development of irrigation on sand country. Learning from others is invaluable.
- Lastly, any project always requires a person to take a leap of faith. Take care to reduce any risks and always investigate the downside.

References

Cowie, J. D 1957: The soils of Manawatu Sand Country. Sand Country Ecology, NZ ECOLOGICAL SOCIETY.

Cowie, J. D. 1963: Dune-building phases in the Manawatu District, New Zealand. *New Zealand journal ojgeology and geophysics* 6 : 268-280.'

Heslop, Patrick. 2001: The Manawatu Dune Field: Enviromental Change and Human Impacts. New Zealand Geographer 57 (2) 2001: 33

MPI, Ministerial Statement Of Responsibility: Statement Of Intent 2013-2018
www.mpi.govt.nz/document-vault/102

Irrigation Acceleration Fund – Summary of Project Progress, updated 28th July 2014.
www.mpi.govt.nz/document-vault/27

The Catalyst Group, Irrigation Efficiency in Rangitikei District, August 2014,
https://www.rangitikei.govt.nz/files/general/LTP-2015-2025-Strategic-Water/Irrigation-efficiency-final.pdf

Costs and Benefits of Irrigated Farmland, Iona McCarthy, 2011, School of Economics and Finance, Massey University, New Zealand.
https://www.property.org.nz/Folder?Action=View%20File&Folder_id=201&File=PINZ%20rural%20presentation%20Iona%20McCarthy.pdf

J. Howes, J. Horne, N. Shadbolt, 2014, A Calculator For Estimating The Profitability Of Irrigation On New Zealand Dairy Farms.
http://www.massey.ac.nz/~flrc/workshops/14/.../Paper_Howes_2014.pdf

Horowhenua District Plan, Part C Rules: Section 19 Rural Zone
http://www.horowhenua.govt.nz/Council/Council-Documents/District-Plan/Operative-District-Plan-2015/

Appendix 1

Interviews
Massey University Dr Alistair Clement, Lecturer in Physical Geography
Elton Mayo, Western North Island Sales Manager, Agricom
Hew Dalrymple, Farmer, Bulls

Appendix 2

Interview questions Dalrymples

Initially some talking about operation they had

1. General size of dunes re-contoured
2. Process/ method to move sand
3. Approx. costs / ha
4. Water supply
5. Rules regarding earthworks
6. Rules regarding water take
7. Pivot vs K-Line
8. Increase in production
9. Rate of water applied
10. Timing and seed resewn and why
11. Pasture survivability
12. Return on investment

This was all conducted as we drove the property looking at was being achieved. It was conducted in no particular order and we jumped back and forth between questions as we saw the operation.