BEFORE THE CHRISTCHURCH REPLACEMENT

DISTRICT PLAN INDEPENDENT HEARINGS PANEL

IN THE MATTER of the Resource Management Act 1991 and the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014

AND

IN THE MATTER of the Chapter 5 Natural Hazards (Part) Proposal (Stage 3)

STATEMENT OF EVIDENCE ON BEHALF OF CHRISTCHURCH COASTAL RESIDENTS UNITED (CCRU) FURTHER TO SUBMISSION 3686

30 January 2016

CONTENTS.

INTRODUCTION

CCRU is an incorporated residents group established to preserve and promote the rights and interests of Christchurch's coastal residents. Accordingly it has particular interest in those provisions in the replacement Plan which impact on coastal properties and communities.

In support of the CCRU original submission 3686 CCRU reaffirms its opposition to the rules in Chapter 5 provision 5.8 and 5.8.8 HFHMA and seeks to have them deleted from the PRDP. This relief is sort based on the following points.

SCOPE OF EVIDENCE

- It is inappropriate for HFHMA to be fast tracked
- Mapping and modelling is based on flawed and unreliable Data
- Inconsistent application of Methodology to establish the HFHMA across areas affected
- Sea level rise has been used for HFHMA calculations
- Not compliant with NZCPS
- Social and economic impact has not be adequately considered.

It is inappropriate for HFHMA to be fast tracked

The Mayor has publicly stated that the HFHMA Hazards are not imminent or earthquake related and therefore as with the Coastal inundation and Coastal erosion aspects removed by the Govt for the same reasons, the HFHMA should also be removed from the fast tracked district plan and dealt with through the normal process. See Christchurch Press articles attached

Mapping and modelling is based on flawed and unreliable Data

The HFHMA mapping and modelling is based on the data from a report supplied by Tonkin and Taylor. This report is now being called into question and is undergoing the process of a second peer review to establish its suitability of use for planning purposes. This review will not be completed at the time of the hearings

The Simon Arnold reports raises further questions regarding the reliability of the methodology used in the Tonkin Taylor report (see attached report and report summary). Tonkin and Taylor have acknowledged to Mr Arnold that there is a straightforward error in the methods used by Mr Ivamy who provided statements of evidence on this issue for the CCC (see attached letter from Tonkin and Taylor).

Inconsistent application of Methodology.

The evidence of Gregory Mark Whyte, Principal Engineer at DHI Water & Environment who submitted evidence for CCC indicates that the Sumner area was modelled differently to other areas and that there were errors in this modelling. This has resulted in areas of Sumner that while being significantly lower than other areas in the HFHMA are rated as less prone to flooding or excluded/ smoothed from the HFHMA. CCRU question the reliability of the data used for other areas.

Sea level rise has been used for HFHMA

The PRDP itself has identified HFHMAs as those areas where in a 500 year flood the water will be greater than 1 meter deep (assuming a sea level rise of 1 meter) or the water velocity (in meters per second) multiplied by the water depth (in meters) exceeds 1.0. This directly links the HFHMA to sea level rise in the methodology and calculations. It is CCRU view that these HFHMA overlay areas that are coastal in nature -namely Sumner, Redcliff and the Southshore/South Brighton estuary areas are Coastal Inundation overlays in another guise and should be removed and considered at a later date with a revised coastal plan as per the Government's direction (see attached screen grab of HFMA overlay for HFHMA of these areas and slides of original coastal Inundation Hazard)

Not compliant with NZCPS

The HFHMA rules refer to compliance with the NZCPS but it is clear that the CCC has applied precaution to the HFHMA where the NZCPS clearly stipulates that technical assessments of Hazard risk under the NZCPS are to be done without precaution.

The NZCPS is breached where:

•The potential impact of coastal hazards has not been assessed "taking into account national guidance and the best available information on the likely effects of climate change on the region or district" contrary to Policy 24 NZCPS. National guidance (Parliamentary Commissioner for the Environment and Ministry for the Environment) and the best available information (IPCC's AR5 report) both suggest that a sea-level rise of 1.0m is unlikely.

•The risk assessment has incorrectly applied precaution in direct conflict of Policy 3 NZCPS. The Parliamentary Commissioner for the Environment, The Canterbury Regional Policy Statement, DOC's guidance note for Policy 3 as well as a compelling amount of case law all stipulate that it is the risk managers and not the risk assessors which are required to adopt a precautionary approach in the face of uncertain science.

•Conversely, Chapter 5 does not contain evidence that the Council is exercising a precautionary approach in risk management and is thereby itself in breach of Policy 3 NZCPS

•There is no evidence that the CCC have analysed the strategies contained in this chapter with a "do-nothing" approach as required by Policy 27 NZCPS

•The Council are not managing coastal hazard risks identified to occur over at least a 100-year timeframe, contrary to Policies 24, 25 and 27.NZCPS. It is now 2016 which entails that the risk assessment spans a maximum of 99 years.

•In these respects, Chapter 5 of the Proposed District Plan fails to "give effect to" the NZCPS and is thereby in breach of 75(3)(b) of the Resource Management Act 1991.

See NZCPS and RMA reference sheet for applicable policies discussed in this section.

Social and Economic impacts.

CCRU believe that the CCC and The PRDP has not adequately considered the social and economic impact of 6500 households affected by provisions 5.8 HFHMA and its associated rules. As the the HFHMA overlay encompass large parts of individual communities the impact of the Rules of 5.8 HFHMA and the non-compliance of building activity will no doubt have a marked effect on these communities.

The CCC own evidence supplied by economist Geoff Butcher (see attached evidence) has indicated not only that he is was able to reach any conclusion in regard to economic justification for FPMA rules in relation to residential land

3.1 In relation to FPMAs, I have only analysed the economic effects of the FPMA in the Cashmere area. I conclude that the FPMA rules are economically justifiable in relation to rural land, but that it is not possible to reach any conclusion with regard to the economic justification of FPMA rules in relation to residential and business land.

But furthermore is likely to have high social costs to areas that are already struggling to recover.

7.4 HFHMAs and a consequential reduction in section availability in the east of Christchurch may hamper recovery of the community on that side of town. Numerous individuals have argued that the slow recovery of that part of the city has had high social costs, and while there is no formal analysis of the impacts of a shortage of sections on the rate of recovery, preventing new building in the HFHMA on that side of the city is likely to exacerbate social problems in the short term.

The CCC evidence of Geoff Butcher also suggests

6.7 A possible alternative rule would be to allow subdivision and building only if the new building had a floor level above, say, a 200 year flood event. The likely cost of this for a particular section is perhaps $15,000 – $20,000 per site. An alternative rule of this nature would possibly avoid most of the flood damage including deaths and injuries at a much lower cost than the proposed rules.

Given the CCC own evidence indicates that there was no analysis done or data compiled, in such that any valid conclusion could be made, CCRU affirms points made in its original submission that the CCC section 32 analysis does not satisfy the requirements of the RMA in that it has failed to consider the adverse impact of the proposed changes on the value of land/property, and on the economic, social or cultural costs to the affected community.

Summary Statement.

CCRU opposes the provision 5.8 and associated rules 5.8.8 HFHMA and seeks to have them deleted from the Proposed Replacement District Plan.

It is CCRU's view that these provisions are not an appropriate way for the council to manage flood hazards. The methodology has been shown to be inconsistent in application and contravenes the NZCPS in its precautionary assessment. The underlying report(Tonkin and Taylor) on which this data is based is now to be peer reviewed for a second time, in an effort to determine if it is fit for purpose for use in the planning process and therefore can not be relied upon to be fair and accurate.

The New Zealand Government has required the removal of all Coastal Hazard aspects from the PRDP and as the HFHMA overlays are founded in methodology based on sea level rise these should also be removed and considered at a later date with Coastal Hazards

The CCC own evidence indicates that little consideration has been given to the Economic, social and cultural effects of the proposed rules and therefore time must be set aside to consider the impact of these rules and the alternative approaches available.

30 January 2016

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Mayor welcomes Government intervention on District Plan Review

Tuesday 29 September 2015

Christchurch Mayor Lianne Dalziel has welcomed the Government's decision to remove coastal hazards from the District Plan Review process.

"I have always been concerned that having coastal hazards in our fast-tracked District Plan Review process did not allow sufficient time for us to discuss these important issues with affected residents, particularly those in coastal parts of our city," Lianne Dalziel says.

"Today's announcement will be welcomed by local residents who have been extremely concerned at the proposed changes to the District Plan and their ability to have meaningful input on the issue of coastal hazards. The fast-tracking of our District Plan Review was always intended to be about earthquake recovery. We do not need to move with the same speed with respect to these longer term issues."

Mayor Dalziel says the conversation around coastal hazards for all coastal communities in New Zealand, including Christchurch, needs to continue. The Council-commissioned Coastal Hazard Assessment Report (Tonkin & Taylor 2015) which was released in July prior to notification of Stage Three of the District Plan Review, will continue to inform this discussion.

Mayor Dalziel has thanked the Ministers for being willing to listen and to intervene on behalf of these stressed communities.

"It has always been my view that we needed a collaborative approach between the Crown, Councils and Regional Councils to establish national guidance on coastal hazards to assist Councils in what can be a challenging policy area to address.

"I realise that our coastal communities have experienced considerable anxiety following the release of the Tonkin & Taylor report and residents have been under pressure to prepare submissions in a tight timeframe. It has been a tough time. We now look forward to working with communities and taking the time to work through how we will adapt to changing coastal conditions, with national guidance and

Christchurch Press article

Controversial Coastal Hazards Zoning dropped 29 Sept 2015

The council immediately amended Land Information Memorandums for those properties to indicate they were in a coastal hazard zone and announced it was proposing through the Replacement Christchurch District Plan (RCDP) to limit new development in the areas considered most at risk.

That sparked concern people would not be able to develop their properties, values in coastal areas would dive and it would become harder and more costly to get insurance.

Christchurch Coastal Residents United spokesman Tim Sintes said the decision to step back was "fantastic news".

"To get a result like this, it's democracy at it's best.

"It has to go this way, with a national standard, rather than ticking off one town after another."

Residents were not opposed to risk mitigation on coastal hazards, he said, only the process the council had taken.

"Our argument was never about climate change. We were disputing the way it was put together and the effectiveness of it. We felt it was very unfair."

Warren Hawke has lived in New Brighton with his family for more than 30 years. When they were "earthquaked" out of their home on Rockinghorse Rd, they moved only a few blocks.

"We're beach people," he said.

"I was a surfer for over 30 years, our kids surf. We're on the beach every day of the year with the dog, just walking on the beach.

"New Brighton has been a long suffering area . . . but there's a tremendous community spirit down there and there a lot of great community groups that are working towards rebuilding the place and I'm sure, now, that that's going to happen."

Dalziel said: "[Tuesday's] announcement will be welcomed by local residents who have been extremely concerned at the proposed changes to the District Plan and their ability to have meaningful input on the issue of coastal hazards.

"The fast-tracking of the District Plan Review was always intended to be about earthquake recovery. We do not need to move with the same speed with respect to these longer term issues."

Public submissions on the proposed new planning provisions were due to close on October 16, but Cabinet has agreed the council can withdraw the provisions in the RCDP.

"This is an absolute win win," Dalziel said.

"It is a great outcome. It doesn't pose a risk to the coastal environment in the sense there is plenty of time to now work through the issues without the pressure of having notified a plan change. It means we can start again and I think that will be a huge relief to people.

"I would have preferred the intervention had happened last year but I don't think anyone should feel what they have already put into the process is a waste of time. A lot of the work that we have done as a council can feed into the development of the national policy statement."

Cr David East, the only city councillor to vote against the coastal hazard provisions in the RCDP, said he was "absolutely ecstatic" at the news the provisions were being withdrawn. He had always been sceptical about the science used to justify them and believed the council was acting too hastily.

Earthquake Recovery Minister Gerry Brownlee said the announcement would spare the thousands of Christchurch residents affected by the planned restrictions on their property use "the mad rush to make submissions by October 16 and the uncertainty for their communities over the already difficult earthquake recovery".

Smith said Christchurch had enough on its plate and did not need to have the added burden of leading the country and the world on how to deal with the issue of climate change and sea level rise.

The Government was proposing both legislative changes and national policy guidance on such hazards as part of its Resource Management Act reform programme.

"More time will also allow contestable advice and normal appeal rights to the Environment Court. It makes sense for the timing of this work to be aligned with national policy. I am satisfied that the existing plans provide adequate interim measures to deal with these risks in the immediate future," Smith said.

Labour MPs Ruth Dyson and Poto Williams said the Government needed to develop a National Policy Statement on natural hazards before councils had to respond to such issues

Statement of expert opinion on the fitness for purpose of the information used by the Christchurch City Council to develop high water overlays in the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014

1. My full name is Simon Harry Arnold. I run my own business that commercialises science base technologies and have done so for the last 15 years. In doing so I am called upon to undertake due diligence on a wide range of natural, physical and engineering applied science to establish its methodological soundness and its fitness-for-purpose. I advise a number of NZ's leading research groups.

2. I have a BA (Hons) in Mathematics and post graduate study in management and policy analysis. For 7 years I was responsible for statistical collection and analysis for the NZ education sector, including multi-decadal forecasting for aspects of it. I have held senior policy roles in the NZ public service and as the policy and strategy advisor to a Prime Minister.

3. I chaired the working group that developed and implemented the current environmental machinery of government in the early eighties, and as CEO of the then NZ Manufacturers Federation in the 1990s I worked on the implementation of the RMA as it impacted on that sector. However, the first time I specifically addressed the process of managing hazards arising from sea level rise was in 2013 when as new Kapiti Coast resident I got involved with the residents group responding to the Kapiti Coast District Councils (KCDC) efforts under the Resource Management Act (RMA) and NZ Coastal Policy Statement (NZCPS) 2010 and the Local Government Meetings and Official Information Act.

4. Since then I have taken a close interest in both the legal and policy framework under which these risks are managed, and the science by which assessments of sea level rise are made. Before expanding on this I should stress that I have not looked at flooding or related matters per se. My evidence is limited to the fitness-for-purpose of the sea level rise assessments as they impact on the high level water overlays.

5. The problems that KCDC faced with advice from the coastal engineering consultants have been documented elsewhere. An independent review found that the advice the local industry had given was not fit-for-purpose, and KCDC has withdrawn the coastal provisions from its Proposed District Plan and deferred consideration of it. In the meantime the coastal residents and KCDC have been working on developing a process designed to avoid the problems had arisen.

6. Three key features of this new process are:

    a. Recognition that it is property owners who carry the primary risk in these situations, and therefore they need to be involved as partners from the beginning of any process leading to the management of them;

b. Specification of the legal framework under which the process is to occur is critical, and this needs to be specified prior to contracting any supporting technical analysis/assessment;
c. Hazard engineering is just one small part of assessing and managing risks on 100 year time frames. Statistics and economics are critical, and the coastal consultancies lack these capabilities (the Kapiti residents insisted on a statistician being included in the independent review, and his contribution was instrumental in removing key errors in the analysis).

7. In my opinion the Christchurch City Council (CCC) has also failed to address these issues in its process and therefore the same issues have arisen with their technical assessment and planning response.

8. As part of my involvement at Kapiti I have reviewed both the NZ legislation and official policy papers on coastal hazard assessment and management, and the international literature on sea level rise. The latter includes the International Panel on Climate Change (IPCC) (2014) 5th Assessment, Working Group 1 Reports, and have read much of the literature referenced in Chapter 8 that deals with Sea Level Rise, and related subsequent publications. I have also been exposed to others in the Kapiti group who have significant capability in the various disciplines involved, particularly law and economics.

9. As a consequence of my involvement in Kapiti and concern over the way poor decisions had been made at significant cost to the community, I took an interest in what was happening in other local authorities. It was clear that the coastal consulting community didn't understand either the legal or methodological requirements for a fit-for-purpose assessment, and local authorities were failing to directly them adequately when employing them.

10. Through this I became aware of *The Statement of Evidence of Mark Christopher Ivamy on behalf of Christchurch City Council* before the Christchurch Replacement District Plan Independent Hearings Panel and *"Coastal Hazard Assessment Stage Two", Tonkin and Taylor (T&T) 2015*. Despite the latter having been completed after the Kapiti PDP process it took no account of the lessons.

11. I therefore reviewed both documents and sent that to both CCC and T&T for comment and asking for them to be reviewed for errors. I attach that letter with my Review (Attachment 1). For convenience I also attach a summary of my Review (Attachment 2). Neither party identified any errors but T&T did acknowledge an arithmetic error but claimed other grounds for their results (Attachment 3). I responded pointing out that T&T was relying on guidance written in 2008 (and relating to a NZCPS from 1994) as being an acceptable basis for undertaking an assessment under the NZCPS 2010. I have had no response. I also had some inconclusive correspondence with CCC on the Review but that failed to address any of the substantive issues raised.

12. I therefore consider the conclusion in the summary "*that T&T 2015 isn't fit for purpose, and any actions taken by the CCC based on it should be withdrawn*" still stands.

13. The Parliamentary Commissioner for the Environment (PCE) subsequently issued a second report "*Preparing New Zealand for rising seas: Certainty and Uncertainty*" (2015). This reinforce the accuracy of my Review, and in particular supports three of my criticisms of the T&T evidence and assessment, namely:

    a. T&T applied precaution when that was inappropriate in a technical assessment, being the prerogative of the CCC;
    b. T&T used unlikely projections of sea level rise. Likely projections are required by Policy 24 of NZCPS 2010; and
    c. T&T variously failed to use appropriate statistical techniques.

14. Specifically the PCE report makes clear:

    a. *Technical assessments of hazard risk under the NZCPS should be done without precaution.* This is so the Council can get best estimates of the risks and the uncertainty in them. This lets it, among other things, decide if it will apply precaution in the management of affected resources (see Section 8.5 of the PCE's report – while she's asking for central government guidance on this matter it is already stated in DoC's guidance on Policy 3 of the NZCPS 2010)
    b. *The RCP8.5 emissions scenario that T&T use for their projections is not a "likely" scenario.* T&T uses this scenario as the basis for what is meant to represent the "likely" effects of climate change and refers to it as being "business as usual". The PCE consistently and correctly calls this the "very high greenhouse gas scenario"
    c. *The statistics need to be got right.* For example in footnote 110 the PCE report discusses the assumptions used by T&T 2015 around accretion. The PCE basically confirms my suggestion that there is little risk on the coast, and states "These predictions should be thought of as 'highly precautionary.'"

15. In summary, any decisions taken in the Replacement Plan that have been based by CCC on either T&T's evidence or assessment on sea level rise will be flawed technically and legally. This is of particular concern because these decisions will have exaggerated the risks and increased the areas affected by the Plan provisions. The cost of those errors will be directly transferred onto the individual property owners.

Simon Arnold

29 January 2016

5 November 2015

Arnold review of Tonkin and Taylor report for the Christchurch City Council:

Coastal Hazard Assessment Stage Two

Background

Tonkin and Taylor (T&T) prepared a report, Coastal Hazard Assessment Stage 2 (T&T 2015), for the Christchurch City Council (CCC) for the purpose of CCC using it to identify coastal hazards on a 50 and 100 year time frame under the Resource Management Act (RMA). Mr Arnold is a mathematician who has had extensive involvement in policy analysis and was involved in the Kapiti process where poor work by coastal consultants led to the Kapiti Coast District Council withdrawing the hazard lines in both its proposed district plan and from the LIMs.

The expert evidence given by Mr Ivamy a T&T employee on behalf of the CCC in the Replacement District Plan Independent Hearings came to Mr Arnold's notice. Mr Ivamy's evidence was on sea level rise and was one of the inputs into T&T 2015. His evidence contained a number of significant legal and methodological errors (including a simple error in arithmetic that inflated the assumed sea level rise).

This led to Mr Arnold undertaken a more extensive review of T&T 2015. This too suffered from legal and methodological errors.

The basic conclusion from the review is that T&T 2015 isn't fit for purpose, and any actions taken by the CCC based on it should be withdrawn.

The bottom line

Mr Arnold *reviews* T&T 2015 and doesn't try to repeat it with the errors corrected. One of the criticisms of T&T 2015 is that one can't tell how the assumptions and errors impact on the reported results making the assessment useless in any subsequent planning and resource management decisions by the CCC or the residents.

However virtually all the errors and assumptions do serve to exaggerate the risks of coastal erosion. A back of the envelope calculation suggests that accretion and sea level rise over the next century are likely to cancel out, leaving little change in the hazard risks over this period.

This however is not robust conclusion; it simply gives an order of magnitude indication of the extent to which T&T 2015 exaggerates. It suggests that the encroachment onto properties T&T 2015 shows is primarily a product of T&T's assumptions and mistakes.

The problems the review found

1. Under the RMA coastal hazard assessment needs to be in accordance with the NZ Coastal Policy Statement. The first NZCPS was issued in 1994 but this was superseded by a new version in 2010 that extensively reworded the provisions around hazard assessment from sea level rise. Most surprisingly T&T 2015 bases crucial assumptions, particularly on sea level rise, on the NZCPS 1994 (and guidance issued in respect of that), not the NZCPS 2010. This significantly exaggerates the risks because NZCPS 1994 refers to *possible* sea level rises; NZCPS 2010 requires the *likely effects* of climate change to be used.

2. T&T 2016 incorrectly applied precaution adding bits for "safety" throughout. Thus it further exaggerates the risk it reports. This too is contrary to the NZCPS 2010 (and DOC's guidance on this) namely that precaution is not to be used in the assessment phase, this being the prerogative of the Council when it comes to managing those risks.

3. They double counted uncertainty in the models they used to do their projection of the shore line and this exaggerates the risks. They used grossly exaggerated limits when estimating the uncertainty compared with what they claimed they were doing.

4. They failed to test their model against history to see if it stacked up in the real world. For example they made no attempt to look at what the coast line did when major storms hit in the past to see if their model was consistent with that.

The legal failings alone make it unfit for use under the RMA.

Soundness of the legal assumptions made by Mr Arnold

The errors made in T&T 2015 fall into two areas: legal interpretation of the RMA and the NZCPS, and the projection of complex systems under uncertainty. In respect of the legal issues Mr Arnold drew on a report "The Kapiti Fiasco" written by retired Principal Environment Court Judge Joan Allin.

The views of CCC and T&T on the Arnold report

Both have had copies of the report with a request for them to identify any errors. Both have responded *without identifying any errors*. T&T have said the arithmetic error in their sea level rise estimates wasn't material, but based this view on a NZCPS 1994 interpretation of what they were required to do rather than the NZCPS 2010 (see problem 1. above). Discussions are continuing with them on this point. CCC has asserted T&T 2015 is fit for purpose based on the standing of T&T and others. Discussions are ongoing on what should now be shown on the LIMs.

Scope of the report

The Arnold review is limited to the sea level rise assumption in T&T 2015 and its assessment of the coastal erosion hazard zones. T&T 2015 also addresses inundation zones. This aspect hasn't been reviewed.

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17 October 2015

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Tonkin and Taylor Coastal Hazards Assessment Stage 2 for CCC

You don't know me from a bar of soap but I started life as a mathematician and my first job was with the then Department of Education responsible for their statistical work including multi-decadal forecast. Later in the early 1980s at the SSC I led the working group that set up the current machinery of government in the environment area, so I have a soft spot for public policy in this area. These days I spend quite a lot of my time doing commercial due diligence on science.

My reason for writing is that I now live on the Kapiti coast and, while not directly affected, have found myself applying much of my past knowledge to the issue of coastal hazard assessments. In that context I've participated in the various reviews of the science that have occurred in Kapiti and in helping to develop a more appropriate way to handle these issues than is current practice[1].

With this background in mind I had a look at the pRDP provisions related to the coastal hazards, starting with the projection assumption for sea level rise from the IPCC. In doing this I reviewed Mr Ivmay's evidence that set out the basis for this assumption. Attachment 1 contains that review.

This finds the evidence wanting, not just at the level of the assumptions but also in places in terms of the methodology. Consequently I started to have a look at the wider Stage 2 report (referred to as T&T 2015 in the attachments) in anticipation of submitting on stage 3 of the pRDP.

The coastal provisions were withdrawn so I put this aside, but now understand that CCC is persisting in using this for LIM annotations so I felt I should complete it and see if by so doing it could help the various parties to back off from unnecessarily fixed positions, and to help get better processes underway.

[1] This is available in draft from the Kapiti CRU group.

Attachment 2 reviews the wider T&T 2015 methodology for the CEHZ and finds it also not to be fit for purpose.

My purpose in writing to you both is to bring this to your attention, and *to give your organisations a chance to correct any errors you may see in what I have prepared*. I have to stress it has just been put together on a pro-bono basis in amongst other priorities, so has had none of the care and attention or other professional input one would expect from a professional study. It is very much E&OE and leaves much to be desired in terms of general finish.

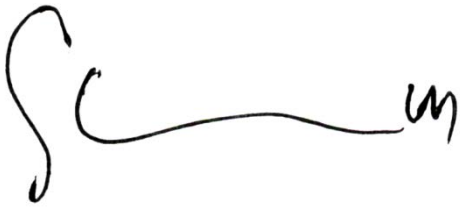
Having said this, some of the mistakes in interpretation of the NZCPS 2010, while currently endemic in coastal consulting profession, are straightforward to check (use of precaution, use of unlikely effects of climate change, separation of hazard risk assessments and risk management).

In terms of going forward I think Tonkin and Taylor should consider whether it wishes this report to continue to be used by the CCC under the RMA and NZCPS 2010. My view for what it is worth is that it would be prudent to withdraw it. CCC has clearly been misled by it as seen by its action in including the results on the LIMs. The conclusion to the second attachment has some suggestions for dealing with the situation on a longer time frame.

Having said this I look forward to any comments you might have on what I have prepared.

Finally it is worth asking if had CCC received a report that said the best estimate of the uncertainty in 100 year forecasts of the CEHZ was that the coast line would be pretty much where it is today but with the uncertainty around that increased, would it have then taken explicit action in the name of precaution to move the hazard zones inland onto residents properties?

Kind regards



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ATTACHMENT 1

Fitness for purpose of the science underlying the coastal management areas and LIM annotations based on an analysis of the *Statement of Evidence of Mark Christopher Ivamy on behalf of Christchurch City Council* (SoE)

Introduction

The Coastal Erosion Management Area and Coastal Inundation Management Area being considered in Stage 3 Christchurch Replacement District Plan Independent Hearings were prepared by Tonkin & Taylor (T&T) for Christchurch City Council (CCC). Mr Ivamy identifies himself as an author of these reports (SoE para 1.4).

This note assesses the understanding of both the legal requirements and the science involved in developing sea level projection as evidenced by the SoE[2]. These projection were used in T&T 2015 to develop coastal hazard zones and this was in turn used by the CCC in developing the now withdrawn pRDP (para 2.1) and also in the LIMs. So in assessing the SoE this review also addresses the fitness for purpose of the coastal management areas used in the LIMs.

It finds that the SoE sea level projection are not fit-for-purpose for use under the NZCPS 2010 and this has significant consequences for the appropriate projections and the coastal management areas used to annotate the LIMs.

In particular it finds the SoE:

- Incorrectly applies the precautionary principal to the assessment of coastal hazards;
- Uses unlikely effects of climate change when it should use likely if, as it purports to, it is to be compliant with the NZCPS 2010. Consequently it incorrectly selects the IPCC projections based on RCP8.5 for use under the NZCPS 2010 when this scenario is an upper bound;
- Fails to provide those who need to manage the hazard risks with either the likelihood of the proposed projections or their uncertainty. Consequently its projections are misleadingly certain[3];
- Assumes that the local sea level rise is the same as the global rises with limited evidence despite warnings by the preferred source (IPCC 2014) that this is unlikely to be the case;
- Relies on MfE guidance that was prepared under the superseded NZCPS 1999 and the superseded IPCC AR4;

[2] This submission is not intended to relitigate the evidence or the decisions already made based on it (although to any reasonable person that will be a consequence).
[3] However T&T 2015 in using this projection to develop coastal hazard lines used the range reported by IPCC for RCP8.5 to develop estimates of uncertainty. See Attachment 2 for a review of this.

- Makes some straightforward errors and questionable assumptions that, if corrected results in the SoE 2115 projections being 0.13 of a metre lower than those used in the pRDP, rather than supporting them as claimed.

A reworking of the projections based on the same assumptions but correcting all these errors leads to the likely projections for the 2015-2115 sea level rise lying between a continuation of the current rate of increase through to 0.81m but with current observations tracking close to the bottom of the range.

These errors have a significant impact on T&T 2015 and lead to a significant overestimation of the inland migration of the 50 and 100 year coastal management areas. The LIM annotations based on it are therefore inaccurate and misleading.

Evaluation of the SoE

The purpose the science

Mr Ivamy's work is applied science to be used to help meet the requirements of the NZCPS 2010 and the RMA as they apply to coastal hazards in Christchurch. More specifically it relates to the of identification of areas "that are potentially affected … giving priority to areas at high risk .." under Policy 24 and the assessment of hazards risks "having regard to … sea level rise [among a wide range of other factors]".

The SoE is silent on whether Ivamy received a brief or took professional advice on the matters he needed to address to meet this need. Neither T&T 2013 or 2015 indicates that CCC set these in the ToR to these assignments. We can only assume he or his employer applied their own judgement despite the NZCPS 2010 being clear that the "NZCPS is to be applied as required by the Act by persons exercising functions and powers under the Act" (p. 7) not by advisers assisting the process.

However even without a clear statement of the information CCC required, the NZCPS 2010 is quite clear on what is required in a number of its provisions.

Paragraph 5.1 of the SoE correctly identifies Policy 24 as the operative provision and that the assessment to be performed is to "take account of … the <u>likely</u> effects of climate change .." [emphasis added, to be addressed later].

However the SoE incorrectly states this "requires the effects of sea level rise to be assessed ..".

In fact Policy 24 requires the "Hazard Risks … to be assessed <u>having regard to</u> … sea level rise" (among a wide range of other factors) [emphasis added]. Those who need to assess hazard risks under Policy 24 need to know more than just possible sea level rise, it needs to be combined with other factors to give an assessment of hazard risks.

The NZCPS 2010 helps here. The Glossary links "risk" to *AS/NZS ISO 31000:2009 Risk management* and in particular the definition of "risk" as the "combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence". So even if sea level rise is the only relevant issue to be considered in assessing hazard risks (and this is most unlikely – matters such as

"influences that humans have had or are having on the coast" and "the extent and permanence of built development" will surely intrude) the science needs to not only provide the "extent" (to use the SoE's terminology) but its likelihood.

Instead the SoE adopts a non-probabilistic approach to sea level rise (it projects single values into the future) and is silent on the likelihood of those projections. Consequently it is not fit-for-purpose when it comes to informing hazard risk assessment, even more so when it comes to "identification of areas at high risk of being affected" under Policy 24.[4]

It is worth noting that the concept of risk as defined by AS/NZS ISO 31000:2009 does mean that the risk will change over time, particularly where the risk is coming from a progressive mechanism such as sea level rise. However it is not obvious that a risk will necessarily increase – while the likelihood may increase over time the consequences may diminish more speedily (e.g. the capacity of those effected to adapt to the changes).[5]

Finally in para 5.9 the SoE offers an interpretation of Policy 3 of the NZCPS 2010 stating it "recommends adopting a precautionary approach when assessing the effects of climate change".

This is incorrect. Policy 3 (1) calls for "a precautionary approach towards proposed activities" [emphasis added]. This policy applies to the management of risks not the assessment of them. Policy 3 (2) which deals with the particular issue of climate change is equally clear: "In particular, adopt a precautionary approach to use and management of coastal resources" [emphasis added].

The whole trigger for the application of the precautionary approach (Policy 3 (1)) is where matters "are uncertain, unknown, or little understood, but potentially significantly adverse". This can only be known once the scientific assessment has been done. If the science ignores the uncertainties and consistently errs on the side of caution as it estimates relevant information it becomes impossible to know the cumulative effect.

This is one area where DOC has developed guidance in respect of the NZCPS 2010, and it is clear: "The application of the precautionary approach is a risk management approach rather than a risk assessment approach" (Page 6 of "NZCPS 2010 Guidance note Policy 3: Precautionary approach" Department of Conservation).

It is therefore surprising that the SoE makes this error (as do T&T 2013 and 2015).

[4] However as noted T&T 2015 uses this concept of risk management. 4.1.6 introduces it and uses it for a number of variables including sea level rise (4.1.4.5). For this reason it is surprising the SoE doesn't provide estimates of uncertainty for its projections.

[5] The CCC's Section 32 report on the Coastal Environment fails to take this into account, and is therefore deficient.

The scientific evidence presented

A number of issues for the science arise from the errors made in the SoE's implicit brief. Others arise from the particular sources used for sea level change and the information selected from them.

In para 5.3 the SoE states: "The IPCC synthesis report (IPCC, 2014) referenced in paragraph 1.6 above is the best available information for assessing sea level rise." This shows a misunderstanding of the respective place and authorship of the Synthesis Report and the Working Groups. The Synthesis Report is the summary for non-scientists and contains at best secondary sources. For the presentation of scientific evidence the expectation would be that the Working Group Reports that include reference to the primary literature would be used, particularly AR5 WG1 Chapter 13 that specifically deals with Sea Level Change.

This is an unnecessary mistake. Identification of AR5 WG1 as the source for the SoE would be no more difficult.

The SoE assumes that future sea level rises in Christchurch "will be equal to the projected global average" (Para 5.4). This is justified by comparing the global increase 1950 – 2000 with Lyttelton 1925 - 2010. No explanation is given for the use of different time scales for the comparison. This should be given since the data is available and the IPCC reports "sea level acceleration results are sensitive to the choice of the analysis time span" (IPCC AR5 WG1 p1150).

Further, given the importance of this assumption and the reliance on IPCC 2014 as the primary source it would be reasonable to expect the SoE to comment on the IPPC finding: "It is very likely that in the 21st century and beyond, sea level change will have a strong regional pattern, with some places experiencing significant deviations of local and regional sea level change from the global mean change." (IPCC AR5 WG1 p1140)

The SoE cites MfE (2008) (para 5.1) and the projections in it (para 5.5) as the national guidance "for consideration when appraising the consequences of coastal hazards". These projections are deterministic (despite some discussion of more probabilistic approaches) and the SoE is deficient in not drawing attention to the fact that this guidance was prepared in the context of the NZCPS 1999 and relies upon the now superseded IPCC AR4.

In particular the SoE fails to note that the MfE guidance includes in its higher assessments "increased contribution from the Greenland and Antarctica ice sheets; carbon cycle feedbacks; and possible differences in mean sea level when comparing the New Zealand region with the global average." In respect of the first factor IPCC AR5 states: "We have considered the evidence for higher projections and have concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the assessed likely range." [6]

[6] This is explicitly referenced in T&T 2015 2.2.1.6 but the relationship to MfE 2008 not drawn.

The implication is that higher projections than those in IPCC AR5 are not likely in the next century, particularly ice sheet contributions that are explicitly accounted for. Thus MfE (2008) has been superseded by IPCC AR5.

The heart of the scientific evidence is in paras 5.9 – 5.12 of the SoE.

In para 5.9 it states "projected global sea level rise values by 2100 to range from 0.27 m … to 1.0 m depending on the emission scenario adopted."[7]

The SoE then states "I consider adopting the 'business as usual' scenario (Representative Concentration Pathways - RPC8.5) is prudent until evidence of emission stabilising, justifies use of a lower projection scenario". The term "business as usual" isn't used to describe RCP8.5 in either of the relevant IPCC AR5 WG1 (Chapters 1 or 8).

The SoE then goes on to cite Policy 3 in support of this prudence, but as has been noted this is based on an incorrect interpretation of the Policy.[8]

Putting this aside RCP8.5 is described in Riahi et al "RCP 8.5—A scenario of comparatively high greenhouse gas emissions" Climate Change (2011) [emphasis added] as "the upper bound of the RCPs" [9] and "a relatively conservative business as usual case". Riahi et al (2011) further states "With few exceptions …. RCP8.5 builds … upon the socio-economic and demographic background, resource assumptions and technological base of the A2r scenario."

This A2r scenario is described in Riahi et al "Scenarios of long-term socio-economic and environmental development under climate stabilization" (2007) as aiming "to be positioned above .. the 75th ... percentile … of the comparable scenario literature, but without all their salient scenario parameters necessarily always falling within this indicative range."

Being the "upper bound" and "above … the 75th … percentile" means RCP8.5 isn't the "best available information on the likely effects of climate change" [emphasis added] as required under Policy 24 of NZCPS 2010, in fact it is not likely (by design).

In para 5.10 the SoE then extrapolates the RCP8.5 projections to 2115 "based on extending a curve through the upper, mid-range and upper projections". The exact method is not disclosed.

In para 5.11 the SoE then adjusts the mid-range projections for 2115 derived in para 5.10 to update from the IPCC base of 1986-2005 (1990 midpoint) to the present (2015).

Two calculations are made to achieve this rather simple adjustment that require explanation.

[7] As an aside the figures from WG1 p 1182 are 0.28m and 0.98m respectively. While the difference is small it is unexplained.
[8] T&T 2013 and 2015 contain similar statements.

First, the SoE doesn't use the actual global observations from 1990 to 2015 of 3.2 mm/year (see IPCC AR5 cited above or for a more up to date assessment: Nerem, R. S., D. Chambers, C. Choe, and G. T. Mitchum. "Estimating Mean Sea Level Change from the TOPEX and Jason Altimeter Missions." Marine Geodesy 33, no. 1 supp 1 (2010): 435). Instead the global projections are adjusted using what appears to be the Hannah & Bell 2012 estimate of Lyttelton Port increase of 1.9mm/year. At the very least this decision not to use the global observations quoted by the IPPC to adjust global projections warrants some justification.

Second rather than *subtract* the actual 1990-2015 rise from the 1990-2115 projection to give a projected 2015-2115 rise the SoE *adds* it on, thereby inflating the 2115 projection from 0.9m to 1.0m. This appears to be a simple arithmetic error.

Adjusting for both of these errors reduces the mid-range projection 2015-2115 from 1.0m to 0.87m.

These errors and the SoE method not being fit-for-purpose under the NZCPS 2010, directly calls into question the validity of the T&T 2015 assessments for the CCC referenced in par 5.7 and used as the basis for the LIMs.

Concluding remarks

Given the legislative requirements and based on IPCC AR5 the SoE should have said the IPCC would see likely sea level rise 2015-2115 in the RCP6.0 range of 0.38 – 0.81m (mid. 0.58m)[10] and hazard risks areas should be assessed across that range. However 15 years into the IPCC's projections the observations are tracking closer to the RCP2.6 scenario and so the bottom of the range could be as low as 0.23m. This would tend to discount the weight put on the risks based on the top end of the range.

Further, in recent times the Lyttelton increases have been below the global increases as measured by satellites so the risk at Christchurch may be even further on the downside. The bottom end of the range is little more than a continuation of the trend at Lyttelton over the last century.

Clearly then any hazard management zones used in the LIMs based on this work are in error and otherwise not appropriate in terms of compliance with the RMA and the NZCPS 2010 in contradiction of how they are represented.

[10] Extrapolated 2100-2015 on basis of 2090-2100 increase.

ATTACHMENT 2

Fitness for purpose of *"Coastal Hazard Assessment Stage Two", Tonkin and Taylor 2015* for use in developing coastal management areas and determining LIM annotations.

Introduction

"Coastal Hazard Assessment Stage Two", Tonkin and Taylor 2015 (T&T 2015) was prepared for the Christchurch City Council and was subsequently used to develop the Coastal Erosion Management Area and Coastal Inundation Management Area that was considered in Stage 3 Christchurch Replacement District Plan Independent Hearings, but subsequently withdrawn, and was used as the basis for LIM annotations.

Attachment 1 deals with one input to T&T 2015, projected global sea level rise, and sets out the problems with that undermines the fitness for purpose of T&T 2015 to either develop coastal management areas or for its use in LIM annotations that purport to represent likely risks from sea level rise.

This Attachment looks at the balance of T&T 2015. It is not in-depth review and is limited to one aspect of that report – the open coast and the coastal erosion hazard zones (CEHZ). It has been done only on the papers, relying solely on the report and appendices. Much of the raw data is not contained in these documents.

The assessment finds that as with the Ivamy SoE, T&T 2015 fails to address the key issues required by anyone managing the resources in question.

It also incorrectly adopts a conservative approach (but not always explicitly in the name of precaution), makes assumptions that are not supported by the information available and double counts uncertainty, all with the direct consequence of inflating the risks. It also has methodological weaknesses that mean it ignores empirical information that would allow CCC to better constrain its assessment of risk. It fails to follow New Zealand guidance for the preparation of probabilistic projections.

The nature of coastal hazard risks

There are two quite different types of risk on the coast, and these require quite different management responses.

First there is the storm risk. In this the risk arises because of the uncertainty of incidence and the intensity of the particular occurrence. What is referred to as 1 in 50 or 100 year storm can occur at any time with probabilities of 2% or 1% p.a. respectively. These risks are like a good many in nature of which seismic events are a familiar example in NZ. There are lots of small frequent events that are expected and therefore don't represent a risk because we take them in our stride. It is the big (i.e. high consequence) but low and uncertain frequency events that create risks that need to be managed.

The second risk is progressive the risk from sea level rise. This is a different kind of risk.

With sea level rise, particularly the possible acceleration of that rise, the uncertainty is around how it will evolve in time. At the decadal timeframe (the life of a typical local authority plan) there is no real uncertainty and hence risk. It is progressive and gradually unfolding (and this is true of any point in time, so by 2100 for example we'll have a good handle on what's happening in 2120 and be relatively unconcerned about it). The uncertainty is in what things will be like in 100 years' time from today's perspective.

Short-term more rapid progressive erosion do create more immediate risks, but like sea level rise the risk comes from uncertainty in the rate of change. The interaction of this risk with storm risk creates high risk areas.

It is therefore critical that the best possible estimate is made of the storm risk and any short-term erosion. Having said this there is equally likely to be considerable history and memory of the recent past that means most of the uncertainty and risk is likely to be known and accommodated within existing management regimes.

Accelerating sea level rise requires quite different management. In the first instance there is no sudden short-term uncertainty and therefore no short-term risk. There is a progressive evolving of the risk with good early warning and these risks impact on only a very narrow class of resource management decisions (those of a longer-term nature). Another feature of the uncertainty and hence risk is that it will always be low for the next 30 odd years because our knowledge improves with time. We never get to the type of risk that the storms create (unless sea ice starts collapsing, for example).

Fitness for purpose of the T&T 2015 CEHZ methodology

With these comments in mind T&T 2015 use a simple linear model to describe the CEHZ (Equation 2). Figure 4-1 shows a sketch illustrating the various components. The report estimates ranges for the various parameters and their uncertainty and then uses these to probabilistically estimate a range for CEHZ over various time periods.

Short-term (storm cut and coastal fluctuations) and long-term components

Because of the way T&T 2015 estimate the short-term components it is simpler to comment on the short and long term components together.

T&T 2015 use three approaches to assessing these components:

First approach: *estimating the middle and upper bounds for the short-term rate.*

T&T 2015 fits a linear model to the historic dune toe position at a number of transects along the shore line (Equation 3). Information from this model with the trend removed is used to produce an estimate of the middle (maximum negative residue) and upper bounds for the short-term rate (they produce two estimates: 3 X standard deviation of residues and the maximum negative progression in the historic time series).

T&T offer no physical model that would justify the use of these statistics in this way. There is therefore little reason to think these particular measures are suitable to give best estimates of likely storm cut and coastal fluctuations going into the future, or are suitable to assess the uncertainty in that estimate.

In particular there is no attempt to relate these various measures to the history of storms, tides and other climatic influencers that are the cause of these deviations. The consequence of this is that T&T 2015 does not use what should be the key information on short-term fluctuations (dates when major storms impacted on the coast line, the intensity of those storms). Nor is information on rates of flow of material onto the coast used to help estimate the real underlying accreting trends.

Further they ignore information from the response to those storms as seen in the transepts at those dates - this would further help quantify the impacts on the coast line. Instead each transept is analysed independently without regard to what was happening on the other transepts at the same time.

Thus there is no robust theoretical model or related empirical evidence for the use by T&T 2015 of these estimates to project future coastal movements or the uncertainty in these projections.

Furthermore even on a superficial assessment, the measures they have selected will significantly overstate what T&T 2015 claims they are representing. By way of example the maximum of the middle and upper bounds across the whole shore line were used in the projections for each individual transept rather than the middle and upper bounds specific to that transept[11]. This will obviously exaggerate the bounds and the middle and upper projections T&T base on them.

If T&T wished to combine the information from each transect then one approach would be to regard each transept as independent samples of a common coastal process[12]. Under those circumstances some form of mean should have be used to give a best estimate of the uncertainty rather than use maximum values. It is axiomatic to observe that the average of a number of samples will be lower than the maximum across them and so the T&T 2015 projections based on these parameters are overstated.

Second approach: *estimating the long-term rate of change*

T&T 2015 fits the same simple linear model to calculate the long-term rate of change as is used for the short-term parameter estimates. However they use a different

[11] T&T 2015 justify this on the basis that: "It was considered prudent to use the maximum value for each indicator within the full dataset as we considered there was no morphological reason why that maximum value could not occur within any cell" (p. 23). Putting aside that prudence is not for them to apply, this misses the basic methodological point that what they are trying to do is to produce for CCC the best estimate of the uncertainty in the short-term fluctuations. The maximum values for each transept are derived from the data using statistical measures that may bear some relationship to the uncertainty (although using doubtful methodology, as discussed). On the other hand the maximum of the maximums has no relationship to a statistically based best estimate of the uncertainty across the coast line, unless T&T are postulating a very unusual physical process for how the coast line evolves.

[12] They won't be because of spatial correlations, but the following point still remains.

dataset (derived from photos) and use Digital Shoreline Analysis System (DSAS) software to undertake the linear regression (Section 4.4.4.4).

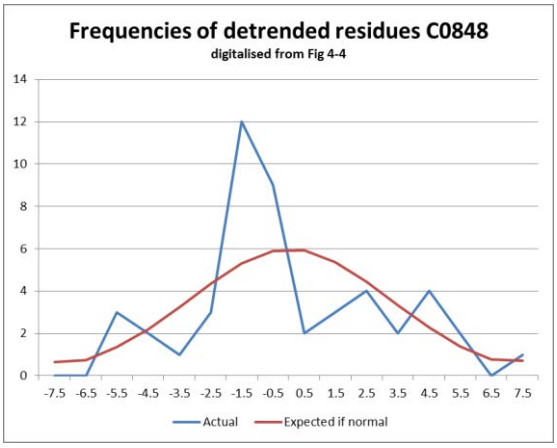
While they use different data both this approach and the approach used for the short-term middle and upper bound are modelling the same process using the same form of linear model. The underlying uncertainty that is regarded in the first approach as being uncertainty in the short-term processes is the same uncertainty that T&T 2015 attributes to the estimation of the rate of long-term change.

The uncertainty is therefore being double counted and consequently it is being inappropriately exaggerated by T&T's methodology.

Further it is unclear how DSAS calculates the uncertainty in the trends from the linear regression, but it is most unlikely that the residues from this modelling exercise conform to the assumptions required for robust confidence limits from simple linear regression (even assuming DSAS adjusts for the spatial correlations).

T&T 2015 claims that these residues are normally distributed ("the distribution of annual residue shoreline movement could be considered normally distributed" p. 19).

Because the residues record impulses from storm events (in various stages of re-instatement depending on the time since the last event) a normal distribution is most unlikely. They are more likely to follow the more complex non-normal distributions characteristic of extreme events (this is well documented in the literature).



In Figure 4-4 T&T 2015 plots the results for Hood Street. This has been digitalised and converted to a frequency distribution graph and compared to the distribution that would be expect if this were a normal distribution (see accompanying graph). This data is not residues from annual movements but clearly it is not normally distributed[13].

The consequence is that statistic calculated for the range of trend lines may not accurately reflect the claimed probabilities.

Putting this aside T&T 2015 use DSAS to calculate the trends in each cell by averaging the trends from each fit passing through that cell. However the highest 90% confidence interval from any of the lines passing through a cell is used for the 90% confidence interval for the whole cell. This is the same mistake as was made when using the maximum middle and upper bounds across the coast line to calculate the short-term rates discussed earlier. Again this arbitrarily inflates the reported uncertainty (and has unknown impact on it).

The separate estimation of the uncertainty (i.e. risk) in the short and long-term components cannot be achieved using T&T 2015's rudimentary model. This is a

[13] The number of observations is at the lower level of what would allow a formal test.

fundamental weakness in T&T's approach since this separation of the uncertainties coming from the unpredictable storms and from the gradually evolving processes of accretion and sea level rise are of fundamental importance to the resource managers (including private owners).

Again using DSAS there is no attempt to fit a physical model to the data. The fit is simply to the passage of time (although spatial relationships do seem to be considered). On the other hand the trend is hypothesised by T&T 2015 to be due to sea level rise and accretion over the historic period. There are independent estimates of these underlying drivers available (measured sea-level and rates of sediment flow down the coast line) that could have been used and it would be expected that some attempt would have been made to relate these to the observed historic coast line (taking account of the impulses from storm events).

Again by not doing this T&T ignore useful empirical information that would better constrain the uncertainty in their estimates.

Third approach: *estimating the lower bound for the short-term rate.*

This approach uses a numerical model (SBEACH) with synthetic storm inputs and an average beach profiles as inputs to model the extent of the expected erosion. Estimates of the extent of storm excursions are used in conjunction with the highest astronomical tide[14] as the lower bound for the short-term component. This estimate is based on the maximum expected excursion for two 100 year events in close proximity. The chances of two 100 year event happening in one year is 0.01% p.a..

This combination of the highest tide with what is stated to be a low estimate of the beach profile derived from a very low probability event (0.01% probability) to give a lower bound is obviously incorrect and greatly exaggerates the lower bound: the lower bound is being represented by T&T 2015 as having a 95% chance of being exceeded, in practice the value actually used will be well under a 0.01% chance.

This greatly inflated lower bound is still below the middle and higher bound T&T 2015 use (above) and this indicates how extreme the T&T estimates are.

It is unclear exactly how T&T 2015 have used the short-term uncertainty estimates in assessing their impact on the 50 and 100 year risks. It appears they have assessed the distribution of shore lines that would occur due to the short-term component in year 50 and year 100 and included this in their modelling of the shoreline in those years (although this isn't completely clear).

In fact the shoreline has memory when it comes to storm events. In a stable shoreline (no sea level rise, no longer-term accretion or erosion) it is the most extreme event over the 50 or 100 years respectively that defines the risk from short-term events rather than just what happens in the year in question.

[14] The perigean spring tide when both the sun and the moon are closest to the Earth.

This becomes more complex to calculate when there are long-term trends (as there are here); at what point does subsequent sea level rise overtake a storm that might have occurred earlier in time?[15]

But for the sake of exposition of how the bounds on the short-term rates could have been calculated and what that says about the bounds actually used by T&T 2015 we'll assume the steady-state case.

Under these circumstances if we are looking for the 5% and 95% bounds to place on the short-term impacts we can roughly identify the types of storms we should be using to estimate these bounds. For the 50 year period we would use a 1 in 17 year event for the lower (5%) bound and a 1 in a 1,000 year event for the upper (95%) bound. For the 100 year period we would use 1 in 33 year and 1 in 2,000 year events respectively.[16]

This confirms that the <0.01% event (i.e. 1 in 10,000 year event) used for the lower bound for the 100 year is grossly exaggerated as a lower bound, and is even 5 times more extreme than an appropriate upper bound.

It should be noted that we can also estimate the 50% threshold in the same way – this would suggest that around a 1 in 70 and 1 in 140 year events should be used for 50 and 100 year periods respectively. Note because the distribution of the magnitude of extreme events is skewed in its (see earlier graph) simulations of this distribution cannot just be based on normal distributions.

This third approach does have the advantage that the numerical model should at least give a theoretical estimate for the extent of the storm cut within the limits of the SBEACH model's assumptions (but this too should be verified).

In comparison (and as noted) the regression model of dune toe position fits a model with little relevance to the physical process being modelled, throws away considerable information that could help constrain the risks, and any derivation of uncertainty from the model looks as though it violates the assumptions of the method being applied and double counts this with trend uncertainty.

Notwithstanding the concerns expressed in T&T 2015 about the potential under-estimation of the SBEACH model the significant differences from the two approaches should have caused T&T to revisit the reliability of the regression approach and the uncertainty derived from it.

[15] Ramsey et al (2012) as cited in T&T 2012 on p. 74 sets out one much more appropriate method to use, and under the NZCPS 2010 Policy 24 it is arguable this would be guidance that should be followed.

[16] For example to calculate the lower 5% threshold for a 100 year period if the annual frequency of exceedance is x then the chance it won't occur is 1-x in any year. Over 100 years the chances it won't occur is 100 ^ (1-x) (assuming independent events) to find the frequency of storm where this is .05 (5%). x= 0.03 solves, this so we want to an annual frequency of exceedance for the storm of 3% or what is called a 1 in 33 year event.

Summary: *short and long-term rates*

To summarise on the estimation of the short and long-term, the physical process being modelled has accretion from the Waimakariri; occurs in the face of common regional sea level rise, cycles of tides and small and large storm events. At each point on the shore the impact of these physical processes is uniquely represented but they all occur at the similar times, at similar intensities and/or vary on common frequencies. There will therefore be a strong relationship between these external events and what happens on each transect, and on what happens on one of them compared with the next.

The model used by T&T 2015 puts all this information aside and simply attempts to describe what happens on any individual transect by the passage of time. This modelling both ignores autocorrelation and over-fits any model (so estimates of rates are biased and errors and hence uncertainty are overstated) and excludes the ability to attribute particular movements to storms, sea level rise or accretion as appropriate.

The particular approach adopted by T&T 2015 of separately estimating the trend component and including uncertainty from that will double count this uncertainty and inflates the risk. Added to this the particular process of storm impulse followed by gradual recovery will produce residues that are not normally distributed and unless taken into account will bias statistics derived from this.

Finally T&T 2015 makes a number of quite arbitrary assumptions about the uncertainty and bounds on the model that significantly inflate the short-term rates particularly.

Dune stability

The dune stability factor (DS) only applies when the effect of the sea level rise and storm action is to erode the base of the dune. When the coast is accreting the potential for these conditions to apply is small. It appears that T&T 2015 apply this factor regardless, even in those cases where the 50 year shoreline is prograding in some transept projections.

It is very likely that the conditions for the inclusion of any DS factor will not be met over most of the 100 year transept projections once the methods have been corrected to more properly reflect likely climate change (sea level rise) and remove other exaggerated uncertainties

Where it is included and the dune is not at risk this creates another exaggeration of T&T's projections.

Sea level rise

The discussion so far has shown that the uncertainty in the factors other than sea level rise can be significantly further constrained than T&T 2015 reports. However the main driver of the 100 year risks is sea level rise. Two aspects of it particularly influence the projections – the assumed sea level projections themselves and the

closure slope from the Bruun analysis, the latter significantly amplifying the impact of the more extreme forecasts.

We will discuss both in turn.

Attachment 1 outlines the issues that arise with the choice of the IPCC RCP8.5 projection for sea level rise and of not taking account of the actual increases through the first 15 years of the IPPC's projection period. Rather than the likely range of projected values by 2115 used by T&T 2015 of 0.62m to 1.27m (mid. 1.0m) the appropriate values would be ~0.23m to 0.81m (mid. 0.58m or lower).

Using the mode closure slope of 0.014 based on an average from Table 4-12 the reduction of the middle estimate of sea level rise by 0.42m (1.0m to 0.58) reduces the average 100 year erosion by around 30 metres[17].

More significantly the middle estimate of 0.58m sea level rise translates to a 41m incursion landward over the next century, less than the maximum rate of accretion of 56m over 100 years (Section 2.2.2).

Thus other factors aside *on this basis the two long-term factors (accretion and sea level rise) would lead to the coast line moving out over the next century and any erosion risks would reduce from what they are today, rather than increase*.

Using instead the long-term trend rates from Table 4-12 the average trend is 0.28m p.a. seaward. This includes an average historic sea level rise of 1.9mm/year that is working against the trend. Adding this back in gives a further 0.14m p.a. accretion (using the mode closure slope), so the accretion without sea level rise is 0.42m p.a. or 42m accretion over the next century, somewhat lower than the Section 2.2.2 estimate.

Even so on this basis the coast is broadly in equilibrium over the next 100 years.

Turning to the closure slopes from the Bruun rule using Hallermeier closure depths. In their guidance Ramsey et al (2012) make it clear that this approach should only be used as a first order approach (p. 73). Further in a section entitled *Beyond the Bruun Rule* (p. 74) it sets out a preferred approach (reference earlier in this review) not using Bruun, particularly where probabilistic methods are being employed (as they are in T&T 2015).[18]

There are two particular points to be made.

First, the parameters using Bruun have considerable impact on the uncertainty - extending the tail of the distribution inland. For example moving from the average mid closure slope of 0.014m/year to the average upper bound of 0.0055m/year

[17] In what follows the full sea level rise has been used for simplicity. T&T 2015 leave the historic rise of 1.9mm/year in the long-term trend term, so the 100 year projections are reduced by 190mm for what is quoted here.

[18] See T&T 2015 that cites Ramsey et al (2012) as supporting the Bruun rule (p. 27) but fails to mention this criticism.

amplifies the impact of T&T 2015's middle 100 year increase of 1.0m from 70m movement inland to 180m[19].

Second, the values in Table 4-12 are arbitrarily selected without any validation from the historic relationship between sea level rise and the erosion that causes; the countervailing accretion that occurs on the coast line; and the actual movement of the coast line. Putting aside the Ramsey et al comments this is regarded as a basic requirement for use of the Bruun Rule particularly when is being used in situation where its assumptions are likely being violated (e.g. an accreting shore line).

While there are a number of problems with the assessment of the long-term factors, the historic movement of the shore line coupled with inferences from the observed sea level rise and accretion could be used to better constrain the uncertainty in the sea level rise impact. In simple terms the closure slope (and its uncertainty) can be derived and therefore broadly validated by using the historically observed rates of shore line movement, accretion and sea level rise.[20]

Again T&T 2015 fails to validate its assumptions against historic data (putting aside its failure to use the recommended methods for this kind of analysis) and therefore likely over states the uncertainties and definitely conceals T&T's own assumptions in the output.

Concluding remarks

T&T 2015 makes some first steps toward attempting to quantify the uncertainty and therefore the risks as now required under the NZCPS 2010.

However it is not fit for purpose on a number of accounts.

First, it fails to follow the requirements of the legislation that defines its purpose. It uses unlikely effects of climate change and it uses precaution in its estimates where that is the sole prerogative of resource managers (and even then not consultants). The assessments of uncertainty need to be best estimates, not corrupted by arbitrary assumptions.

In many respects this failing is due to a failing by CCC to properly direct T&T on these matters, but T&T should be aware of these issues. Both parties should improve their access to legal advice on these matters. In the case of the use of precaution this is already the subject of guidance from DoC.

Second, it falls down because it fits simple models to the coast that are not driven by the physical phenomena of interest. The models used are not really capable of quantifying the uncertainty where the task in hand is to project a complex system 100 years into the future.

While this is contrary to the current guidance for probabilistic forecasts (Ramsey et al 2012) a more basic problem is the lack of empirical validation of T&T's assumptions.

[19] Approximately 60m increased to 150m using T&T 2015's adjusted sea level rises.
[20] The Bruun rule is after all a simple model that says that these will move in proportion.

This leads to the uncertainty being unconstrained by the historic record and consequently the risks are exaggerated.

In applying the simple models it does, T&T make some quite straightforward mistakes that only further serve to exaggerate the results. T&T should improve the level of statistical and risk management input it has into these types of studies.

Third, T&T fails to appreciate that quantifying uncertainty (the main task in hand) is corrupted the moment arbitrary assumptions are imposed on the data that exaggerate uncertainty. This problem is particularly acute where the assumptions are hidden at early stages of the analysis.

This stems from a more widespread misunderstanding amongst coastal scientists and engineers of when matters require professional judgements and opinions, and when those judgements need to be exercised by those carrying political not professional accountability.

If in the name of precaution the CCC wishes to use more conservative estimates of the long-term risks (and thereby create risks for existing property owners largely in the name of protecting its own interests), the CCC is required under the NZCPS 2010 to do that explicitly.

T&T's duty of care is to give best estimates of the uncertainty within the limits of assumptions that are consistent with the legal framework being operated under to enable the CCC to make that judgement (and the political process to judge in turn).

In practice each of these three failings overlaps. Precaution in the assessments is not permitted by law, arbitrary assumptions end up being used when more complex empirical models are not used etc.

or all these reasons the T&T 2015 assessment is not fit-for-purpose for use under the RMA and NZCPS 2010. The user (in this case the CCC) ends up being misled by the assessment and incorrectly using it (as is evidenced by them being recorded on the LIMs).

Tonkin+Taylor

Job No: 851857.002
28 October 2015

arnold.co.nz
PO Box 16 135
Te Horo 5544

simon.arnold@arnold.co.nz

Attention: Simon Arnold

Dear Mr Arnold

Tonkin + Taylor Coastal Hazards Assessment Stage 2 for CCC

Thank you for your letter dated 17 October 2015 regarding your concerns on our report for Christchurch City Council and the associated statement of evidence prepared by our Mark Ivamy. I am responding to you on behalf of Doug Johnson.

We are still in the process of evaluating your comments and discussing with Christchurch City Council any potential changes that might result from this process. This has also been affected by my absence on leave until last weekend.

At this stage we do accept that there is a straightforward error in the statement of evidence of Mr Ivamy in regard to his adding, rather than subtracting historic sea level rise (Ivamy SOE, Section 5.7 (b)). However, we note that this was one of two methods which Mr Ivamy used to determine the value of sea level rise to apply at 2115, with the second method based on the MfE (2008) guidance providing a higher value that was rounded to 1.0 m. Therefore, in our opinion, this error does not materially affect his evidence to use 1.0 m sea level rise for 2115.

We will review the other matters raised in your letter as part of our ongoing work for Christchurch City Council.

Kind regards

Richard Reinen-Hamill
Natural Hazards Business Leader

c.c. Dr Karleen Edwards, Chief Executive Christchurch City Council

28-Oct-15
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SUBMISSION ON THE PROPOSED CHRISTCHURCH REPLACEMENT DISTRICT PLAN

Clause 6 of Schedule 1, Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014 (OIC)

STAGE 3

To: Christchurch City Council

District Plan Submissions
PO Box 73013
Christchurch Mail Centre
Christchurch 8154

By email: dpreview@ccc.govt.nz

NAME OF SUBMITTER:

1. **Christchurch Coastal Residents United (CCRU)** (in the process of being incorporated)

Address: c/- Lane Neave
PO Box 2331,
Christchurch 8140

Contact: Amanda Dewar

Telephone: 03 364 6451

Email: amanda.dewar@laneneave.co.nz

PROPOSAL THAT THIS SUBMISSION RELATES TO:

2. This is a submission on Stage 3 of the proposed Christchurch Replacement District Plan (**Replacement Plan**), which was publicly notified on 25 July 2015.

TRADE COMPETITION STATEMENT:

3. CCRU could not gain an advantage in trade competition through this submission.

SPECIFIC PROVISIONS THAT THIS SUBMISSION RELATES TO ARE:

4. This submission relates to specific aspects and provisions of the following parts of the Replacement Plan:

   (a) **Chapter 5: Natural Hazards**

      (i) 5.8.8 High Flood Hazard Management Areas Activities and Earthworks

   (b) **Planning Maps and Natural Hazard Planning Maps**

      (i) Planning Maps and Natural Hazard Planning Maps 2, 6, 13, 26, 27, 33, 34, 40, 41, 47, 48, H4, H27, and H29 which contain the High Flood Hazard Management Areas.

SUBMISSION:

Background

5. CCRU is a residents group established to preserve and promote the rights and interests of Christchurch's coastal residents. Accordingly it has a particular interest in those provisions in the Replacement Plan which impact on coastal properties.

High Flood Hazard Management Areas

6. CCRU opposes the rules in 5.8.8 High Flood Hazard Management Areas and seeks to have them deleted as the provisions are not an appropriate way for the Council to manage flood hazards, and because Council has not followed a full and fair planning process.

7. The approach taken by the Council imposes very onerous restrictions on residents within High Flood Hazard Management Areas which limits the fair and reasonable development their properties and the surrounding area, and as a result significantly reduces the value of their properties.

8. The proposed planning changes will likely deter investment by residents and businesses into developing areas identified as High Flood Hazard Management Areas and also the surrounding areas, with the result that those neighbourhoods will decline and suffer socially, economically and culturally.

9. The Council's Section 32 analysis does not satisfy the requirements in the Resource Management Act 1991 (**RMA**) in that it has failed to consider the adverse impact of the proposed changes on the value of land/property, and on the economic, social or cultural costs to the local community.

10. The Council did not properly consult with those affected by these rules, nor did it allow sufficient time for them to understand the impact of the proposed changes on the value of their land, or the economic, social or cultural costs to their communities.

11. The provisions take an unnecessarily restrictive and harsh approach in response to risk that has a low probability of occurring.

12. The Council has not made readily available the reports that the provisions are based on. This means that those residents who wish to understand the underlying science/ modelling behind these Areas have been unable to do so.

13. It is not clear from the limited Section 32 Report what modelling formed the basis for a number of the High Flood Hazard Management Areas identified on the planning maps, in particular those in Sumner.

14. The Council has failed to properly peer review the reports that the High Flood Hazard Management Areas are based on.

15. The Council has not identified or properly investigated other options for achieving its objectives in relation to high flood hazards or for managing or mitigating the hazards.

16. The overarching objectives and polices relating to high flood hazards have already been decided in Stage 1. This is unfair on affected residents who were unaware of the relevance and potential significance of those provisions when they were notified for submissions, as the rules relating to those objectives and polices have been notified in a later Stage.

General

17. In addition to the above, CCRU opposes the Replacement Plan in part for the following reasons:

(a) It will not promote sustainable management of the Canterbury Region's resources;

(b) It will not achieve integrated management of the effects of the use, development or protection of land and associated resources of Christchurch;

(c) It is otherwise inconsistent with the relevant parts of the Canterbury Regional Policy Statement;

(d) It is otherwise inconsistent with the relevant provisions of the RMA, including the purposes and principles of Part 2;

(e) It does not represent the most appropriate means of exercising the Council's functions under section 31 of the RMA;

(f) It does not represent the most appropriate plan provisions under section 32 of the RMA.

DECISIONS SOUGHT BY THE CCRU:

18. CCRU seeks the following decisions in relation to Stage 3 of the Replacement Plan:

(a) The deletion of 5.8.8 High Flood Hazard Management Areas Activities and Earthworks rules and the High Flood Hazard Management Areas from Planning Maps and Natural Hazard Planning Maps including 2, 6, 13, 26, 27, 33, 34, 40, 41, 47, 48, H4, H27, and H29.

(b) Any further, other or consequential decisions or amendments to address the matters raised in this submission.

01 RULE 5.8.8
02 PM HIGH FLOOD HAZARD

CCRU WISHES TO BE HEARD IN SUPPORT OF ITS SUBMISSION:

19. If others make a similar submission, CCRU will consider presenting a joint case with them at a hearing.

CHRISTCHURCH COASTAL RESIDENTS UNITED by its

Solicitors and authorised agents **LANE NEAVE**

Per:

AC Dewar/ SC Reese

Date: 4 September 2015

BEFORE THE CHRISTCHURCH REPLACEMENT DISTRICT PLAN INDEPENDENT HEARINGS PANEL

IN THE MATTER of the Resource Management Act 1991 and the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014

AND

IN THE MATTER of the Chapter 5 Natural Hazards (Part) Proposal (Stage 3)

STATEMENT OF EVIDENCE OF GEOFFREY VERNON BUTCHER ON BEHALF OF CHRISTCHURCH CITY COUNCIL

ECONOMICS

21 JANUARY 2016

Simpson Grierson
Barristers & Solicitors

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CONTENTS

1. INTRODUCTION

1.1 My full name is Geoffrey Vernon Butcher. I am a Director of Butcher Partners Ltd, an economic consulting company in Christchurch.

1.2 I gained an MA (Hons) in Economics from Canterbury University in 1978, and have 35 years of experience as an economist, including periods of employment at the NZ Institute of Economic Research and Lincoln University where I lectured in the areas of business economics, cost benefit analysis and economic impact analysis.

1.3 I have undertaken numerous economic impact and cost benefit analyses for a wide range of industries. In the 1980 and 1990s I undertook cost benefit analysis of flooding in the Heathcote River. More recently I undertook analysis which underlay the Proposed Plan Change 1 to the Canterbury Regional Policy Statement and I prepared a report and economic evidence on behalf of the Christchurch City Council (**Council**) for the related Environment Court Hearing in 2011. This report examined the economic costs and benefits associated with urban form and city planning, with particular focus on the provision of infrastructure assets.

1.4 I have appeared as an expert witness on economic impacts and economic efficiency in numerous hearings before councils, commissioners and the Environment Court on Resource Management Act-related matters.

1.5 I have been engaged by the Council to provide evidence in relation to the proposed rules which restrict development in areas designated as Flood Ponding Management Areas (**FPMAs**) and High Flood Hazard Management Areas (**HFHMAs**).

1.6 I have also previously provided evidence to the proposed Replacement District Plan (**pRDP**) Hearings Panel regarding rules for land beneath and adjacent to high voltage electricity lines.

1.7 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014 and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions that I express, and that this evidence is

within my area of expertise, except where I state that I am relying on the evidence of another person.

1.8 The key documents I have used, or referred to, in forming my view while preparing this brief of evidence are:

(a) the proposed policies and rules covering the FPMA and HFHMA;
(b) a report produced for council by DHI entitled "Christchurch City High Flood Hazard: District Plan Review"; and
(c) the section 32 Natural Hazards Chapter prepared by Council.

1.9 I have been provided with various reports by the Council and have asked them to provide additional information on the properties affected. At my request Council has asked their consultants to provide me with additional information on the degree of potential flooding with and without the proposed rules, and this information has been used by NIWA to estimate the costs of damage due to this flooding.

2. SCOPE

2.1 I understand that this hearing is considering, amongst other things, whether it is appropriate to have rules covering activities which may take place in FPMAs and HFHMAs which are shown on the attached plan (**Attachment A**). This plan is included in the pRDP.

2.2 My understanding is that the rules will discourage subdivision and new construction on this land through non-complying status of these activities. My evidence discusses the costs and benefits associated with those rules, as opposed to an absence of rules which permitted the land to be developed in the same way as other adjacent land, or less restrictive rules which better achieve a balance between costs and benefits and promote the efficient use of resources.

2.3 By way of context, I understand that there may be other planning constraints on subdivision and new buildings in the relevant FPMAs and HFHMAs based on other zoning (for example, restrictions on development of rural land). I note that my evidence focuses specifically on the economic analysis of the FPMA and HFHMA planning rules.

3. EXECUTIVE SUMMARY

3.1 In relation to FPMAs, I have only analysed the economic effects of the FPMA in the Cashmere area. I conclude that the FPMA rules are economically justifiable in relation to rural land, but that it is not possible to reach any conclusion with regard to the economic justification of FPMA rules in relation to residential and business land. To the extent that the new FPMA rules re-state operative flood ponding rules, the new rules do not add any costs to existing land owners. FPMA rules are potentially justified in principle from an economist's perspective because there is an externality (where those who bear the costs of an action (the landowners in the FPMAs) are not the same as those who bear the benefits (the landowners downstream), and therefore a market solution will not work.

3.2 In relation to HFHMAs, the difficulties of quantifying the benefits of the rules in reducing likely flood damage costs means that I cannot say whether these benefits exceed the costs of the rules in terms of losses of land value. Hence I cannot say whether the proposed rules are likely to constitute an efficient use of resources. I compare the costs of the proposed rule to the much lower costs of a rule which merely sets minimum floor levels, and suggest that the latter may be a better rule. However, I note that to confirm this would require more information about flood damage costs under each of the proposed rules.

3.3 In the case of HFHMAs, rules are not justified in principle on the basis of an externality because there is no externality. Those who benefit from the reduced flooding are the same landowners who suffer the costs of the rules in terms of reduced land values. From this perspective a free market may lead to an efficient use of resources. However, Council may consider that rules are justified on the basis of public ignorance of the true facts relating to potential flood damage, or that if there is severe flooding then there is likely to be an externality when landowners request compensation from Council, and hence the general public, for having permitted building on flood-prone land. I note that the rules are also directed by a higher order planning document (the Canterbury Regional Policy Statement) and the Council has to give effect to this in its plan.

3.4 In the absence of other planning controls, the rules would reduce the availability of land for subdivision and for building on. This may have some impact on section prices, and may negatively affect the rates of social recovery in the eastern part of Christchurch. The rules are unlikely to reduce levels of economic activity and employment.

3.5 Limitations to these conclusions include a lack of information in some areas and an assumption of risk neutrality. The lack of information is unlikely to change the conclusions with regard to rural land in the Cashmere FPMA. If there is a significant level of community risk aversion, particularly with regard to events which affect large numbers of people and where effects may include serious consequences such as personal injury or death, this would shift the balance in favour of the proposed rules.

3.6 In this evidence I set out:

(a) a background to the economic justification of regulation;
(b) an economic analysis of the FPMA in the Cashmere area;
(c) an economic analysis of the HFHMAs;
(d) an analysis of the wider social impacts of FPMAs and HFHMAs; and
(e) the limitations to my analysis.

4. BACKGROUND – ECONOMIC PURPOSE OF REGULATION

4.1 Regulation is justified where there is market failure due to externalities (where those who bear the costs of an action are not the same as those who bear the benefits) and lack of information to market participants.

4.2 The proposed rules for FPMAs respond to an externality where people subdividing or building in the FPMA get a benefit, but this imposes a cost on people downstream who suffer worse flooding as a result of the subdivision or building.

4.3 The proposed rules for HFHMAs respond to a situation where those who own the land are, in Council's view, likely to be unaware of the true costs of flooding in extreme events, and hence are likely to make poor investment decisions. Council may also be of the view that when the true costs of flooding become known, those who suffer the costs will argue for compensation from

the Council and hence from the rest of the community, which creates an externality. The proposed rules would prevent this externality from occurring.

5. ECONOMIC EFFECTS OF FPMAs

5.1 There are broadly three FPMAs in the pRDP:

(a) the FPMAs in the Hendersons Basin, Cashmere Stream floodplain, and Hoon Hay Valley and Cashmere-Worsleys ponding area (**Cashmere FPMA**);
(b) the Cranford Basin FPMA; and
(c) the Lower Styx FPMA.

5.2 I have only completed an analysis of the economic effects of the Cashmere FPMA because:

(a) I understand that the Cranford Basin FPMA is largely covered by a roading and stormwater designation, and in any case the data required to complete this analysis is not available; and
(b) I have not been asked to complete an analysis of the Lower Styx FPMA (the FPMA is 134 ha, 40 ha of which is residential land).

5.3 In periods of heavy rain, water can be impounded in FPMAs and released slowly over a period of days or even weeks, rather than immediately. The detention of water reduces levels of flooding in lower reaches of the river from what they would otherwise be, hence providing significant community benefits to landowners who would otherwise be flooded. The FPMA rules that prevent subdivision or development of this land ensure that the land continues to be available for ponding. However, the rules also impose a community cost on landowners in the ponding area who face limitations on their use of their land.

Cashmere FPMA

Benefits

5.4 The benefits of the proposed rules in reducing flood damage may be seen as the difference in flood damage with the rules compared to likely flood damage in the absence of the rules. DHI, an engineering consultancy, has developed flood models for the Heathcote catchment. DHI was asked to estimate depths

of water downstream of the Cashmere FPMA in various flood events. The chosen events were a 10 year flood[1], a 50 year flood and a 200 year flood The depths of water were calculated under two scenarios. In the first scenario the proposed rules are in place, and in the second the rules are not in place and private land is filled for subdivision and building of residential housing, and is no longer available for ponding purposes.

5.5 NIWA has a model named RiskScape, which is designed to calculate flood damage with various depths of water at various locations. It does this by taking the DHI flood depths, comparing this to known floor levels of each property in the flood plain to calculate levels of flooding with each property and house, and using known flood damage to houses and property for various levels of inundation. The NIWA model provided estimates of damage for each flood event under the two scenarios. The difference in damage for a given flood event was deemed to be the benefit of the proposed rules. An annual average benefit was then calculated using a standard procedure to estimating the average damage over a given range of flood events (e.g. all events between a 10 year and 50 year event) and multiplying this by the range in probability of such events. The results are shown in Table 1 below.

5.6 The difference in expected Annual Damage ($1.495 million per year) is shown towards the bottom of the table, and this annual damage is converted to a Net Present Value under various terms and discount rates at the bottom of the table.

1 A flood which is expected to happen once every 10 years.

Table 1. Damage of Various Flood Events and Estimated Difference in NPV with Ponding and Without Ponding (NPV $m)

	A Damage for event ($000) RiskScape	B Annual Prob of Exceedance	$C = B^{e-1}-B^{e}$ Difference in probability	$D = (A^{e}+A^{e-1})/2$ Average damage over interval ($000)	E = C x D Ave Annual Cost ($000 / yr)
With Ponding					
0 yr event	0	1.00000			
10 yr event	2,031	0.10000	0.900	1,015	914
50 yr event	25,449	0.02000	0.080	13,740	1,099
200 yr event	66,016	0.00500	0.015	45,733	686
Ultimate event*	330,080	0	0.005	198,048	990
TOTAL					**3,689**
Without Ponding					
0 yr event	-	1.00000			
10 yr event	3,325	0.10000	0.900	1,662	1,496
50 yr event	32,577	0.02000	0.080	17,951	1,436
200 yr event	89,243	0.00500	0.015	60,910	914
Ultimate event*	446,213	0	0.005	267,728	1,339
TOTAL					**5,184**
Difference					
0 yr event	-	1.00000			
10 yr event	1,294	0.10000	0.900	647	582
50 yr event	7,128	0.02000	0.080	4,211	337
200 yr event	23,227	0.00500	0.015	15,177	228
Ultimate event*	116,133	0	0.005	69,680	348
TOTAL					**1,495**
NPVs				100 yrs	200 yrs
7 %				$21 m	$21 m
5 %				**$30 m**	**$30 m**
3 %				$47 m	$50 m

* The cost of an "Ultimate event" is assumed to be 5 times the cost of a 200 year event. Changing the factor from 2 to 20 changes the NPV damage from a Base Case $30m to $26 million in the former case and $35 million in the latter case

5.7 The Net Present Value (**NPV**) of this $1.495 million per year difference in damage with and without the rules is $30 million at a 5 % discount rate[2] over 100 years. Approximately $23[3] million of this is associated with ponding on rural land and $7 million with ponding on residential and business land.

2 A 5 % discount rate is believed to be appropriate in this context. While Treasury currently uses a discount rate of 7 % for infrastructure projects, there are strong arguments in favour of a lower discount rate for projects such as Hendersons Basin. A lower rate reflects a "Social Rate of Time Preference", and may also be consistent with the discount rate implicit in the land values with which these flood damage costs are being compared. Land values reflect the discount rates required by those investing in land for future development. See NZIER *Insight* no. 32/2011 for a discussion of the issues surrounding discount rates.

3 60 Ha of business and residential land and 200 Ha of rural land changes state. $30m x 200 / (200+60) = $23m. This assumes that ponding depths are the same on average over all land type. Ponding may be deeper on rural land, which would increase the damage associated with rural land and reduce that with other land.

5.8 This figure includes the quantified benefits of reduced property damage as estimated via the RiskScape model, but excludes various unquantifiable benefits such as reduction in a loss of property access, personal injury, and stress to property owners who worry about flooding even when heavy rain does not lead to a flood. There may also be some benefits to upstream properties which are not captured in the hydrological modelling. The calculated NPV benefits of the rules assume that the reduction in flooding starts immediately, and would be lower if it was assumed that in the absence of the rules a buyer of the land would not develop it for some years, and hence the flooding would not occur for some years. If the delay was ten years, then the NPV benefits of the rules would drop from $30 million to $18 million, excluding non-quantifiable benefits. On the other hand, it should be noted that the flood events were calculated by DHI under the assumption of "No climate Change". My understanding is that had the models been run under the "Climate Change and sea level Rise" assumption, the differences in damage with and without the rules would be greater, and hence so would the NPV Benefit of the rules

5.9 These benefits are expected to be split between 200 Ha of rural land (estimated $23 million) and 60 Ha of residential and business land (estimated $7 million). This split is very approximate, and it is possible that the quantifiable benefits from the FPMA rules on rural land are greater than $23 million and on residential and business land are less than $7 million.

Costs

5.10 The costs of the FPMA rules restricting the use of rural land were estimated as the difference in land value with the rules in place and without the rules in place. This was calculated by comparing average marginal rateable values of rural land per Ha within the Cashmere FPMA and immediately adjacent to the FPMA, where the proposed rules do not apply. The difference is very approximately[4] $100,000 per Ha. Multiplying this by the 200 Ha of private rural land gives a cost of the proposed rules of approximately $20 million, which is less than the combination of the $22 million of quantifiable benefits and the various unquantifiable benefits resulting from the FPMA rules. Therefore, I conclude that the rules as regards rural land will lead to an efficient use of resources.

4 The measureable differences in value reflect not only the rules, but also other aspects of land quality including its and suitably for, and cost of, subdivision for residential use. Also, the full force of the proposed rules is not yet in place, so it is possible that the difference will increase once the rules are in place.

5.11 The net benefit of the FPMA rules on the 639 residential and business properties in the Cashmere FPMA is less clear. While the gross benefits are estimated to be $7 million, and the likely range is $5 – 10 million, this equates to only $8,000 – $16,000 per affected property. This may be less than the cost to the landowners of not being able to build or subdivide in the Cashmere FPMA as a result of the rules. There are 10 vacant properties and 107 sub-dividable properties (greater than 900m^2).

5.12 The benefits of the FPMA are enjoyed by the wider public who would otherwise be affected by flooding, but the costs are incurred by the landowners in the FPMA. These costs are imposed at the time the rules change the value of the land. The proposed rules are in part a re-statement of existing policies and rules which limit excavation and filling of rural land in the Cashmere FPMA. To this extent the rules do not impose any additional cost on current landowners.

6. ECONOMIC EFFECTS OF HFHMA

6.1 HFHMAs are those areas where in a 500 year flood the water will be greater than 1 metre deep (assuming a sea level rise of 1 metre) *or* the water velocity (in metres per second) multiplied by the water depth (in metres) exceeds 1.0.

6.2 The proposed rules for HFHMAs will make it difficult to subdivide sections, including the 1,300 sections which are greater than 900m^2 and potentially suitable for subdivision under current rules, and difficult to put up new buildings on sites including the approximately 3,400 vacant sections. This imposes costs on landowners who will be able to use their sections only in limited ways.

6.3 The rules will be justified from an economic efficiency perspective if the costs of the rules to those landowners are less than the cost of damage, injury and death due to flooding if the rules were not in place and the sections are able to be subdivided or built on.

Impact of HFHMA rules on landowners

6.4 The likely cost of the imposition of the HFHMA rules in reducing the potential use of the section is of the order of $80,000 per site[5], being the difference between the value of the site if able to be used for housing and the value of the site with its next best alternative use, which includes use as a reserve or possibly as a wetland area into which stormwater run-off can be directed for treatment prior to discharges into the Heathcote or Avon rivers.

6.5 A benefit of the HFHMA rules is that property damage is avoided to buildings/subdivision that would occur if the HFHMA rules were not in place. Flood water depth of > 1.0 metres and the water velocity factor (i.e. the conditions for the imposition of the HFHMA) would be likely to lead to damage to a house and contents of approximately $101,000 per site[6].

6.6 This $101,000 cost occurs only in a rare event (a 500 year flood). Without knowing the probable level of injury and death in a 500 year event, and the depth and speed of water, and hence damage, injury and death, in more common flood events it is not possible to estimate the likely annual average damage cost and hence the NPV of damage costs. It is this NPV of damage that needs to be compared with the $80,000 loss of land value in order to conclude whether the HFHMA rules will lead to an efficient use of resources. In the absence of an estimate of NPV damage, no conclusion can be drawn.

6.7 A possible alternative rule would be to allow subdivision and building only if the new building had a floor level above, say, a 200 year flood event. The likely cost of this for a particular section is perhaps $15,000 – $20,000[7] per site. An alternative rule of this nature would possibly avoid most of the flood damage including deaths and injuries at a much lower cost than the proposed rules.

6.8 I note that the costs of damage in Flood Hazard Areas are generally not an externality because the costs of losing the use of land under the HFHMA rules accrue to the same landowners who also benefit from the reduced property damage and reduced risk of death or injury from the HFHMA rules. From an

5 This is a very rough approximation. It is based on an assessment of section values in the HFHMAs and an expectation that the value will be perhaps $20,000 / section-equivalent as an addition to reserves.

6 This is based on analysis of flood damage for various depths of water undertaken by Harris Consulting, adjusted to current prices. No data is available on combined flood depth and velocity figures. See Harris, S. Climate Change Case Study: Assessment of the Impacts of Sea Level Rise on Floodplain Management Planning for the Avon River. For CCC 2008

7 Placed and compacted fill costs perhaps $60 - 80 / m3, and a 150 m2 house will require a raised footprint of perhaps 200 m3 at a cost of around $15,000. A cheaper alternative is likely to be a house on higher piles.

economics perspective then, this rule can be justified primarily by information failure. That is, on the basis of individuals being unaware of where their own best interest lies, and Council making a judgement call on their behalf. However, Council may also be concerned that the damage would become an externality if, for example, homeowners with flood damage sued Council for letting them build in an unsuitable place. The Red Zone in Christchurch is an example of private costs becoming a public cost and hence an externality.

7. WIDER SOCIAL IMPACTS OF THE FPMA AND HFHMA RULES

7.1 The proposed rules will prevent some thousands of properties being rebuilt on. This is likely to increase the price of sections, or at least stop them falling. While the approximately 7,000 affected residential properties are less than 4% of total Christchurch properties, the 3,400 residential properties which are currently vacant in the HFHMA and the Cashmere FPMA are a significant number in terms of long term average demand for sections and could materially affect prices. The potential impacts on section prices are even greater when one notes that more than 2,100 of these residential sections are 800m^2 or more and would be potentially subdivisible (this includes more than 1,400 which are more than 900m^2 and are able to be subdivided under existing Living 1 rules).

7.2 The financial losses arising from the proposed rules fall on the landowners at the time the proposed, or similar, rules are imposed. In the HFHMA the costs are likely to fall to a significant extent on central government as owner of the Red Zone land, which encompasses a significant proportion of the residential land in High Flood Hazard areas. The costs in the Cashmere FPMA fall on current property owners to the extent that the proposed rules extend controls on subdivision and building. To the extent that the rules replace existing rules which limit excavation and filling in the ponding areas, then the cost has already fallen on those who owned the properties at the time the rules were put in place and there is no additional cost to current owners.

7.3 It is unlikely that the rules will materially affect opportunities for economic growth and employment. There have been numerous subdivisions completed since the earthquakes, and a number of commentators now believe that there

is, if anything, an excess supply of sections.[8] Reducing the number of buildable sections in the HFHMA and FPMA is unlikely to materially affect rates of economic activity in residential construction. The only concern is that the sections which are in the HFHMA include a significant number that have, historically, been in medium to low income areas, whereas most of the new subdivisions have more expensive sections. On the other hand, many of the sections in the HFHMA are likely to require more expensive foundations than are sites on firmer and higher ground, so the price advantages may be less than it seems at first glance.

7.4 HFHMAs and a consequential reduction in section availability in the east of Christchurch may hamper recovery of the community on that side of town. Numerous individuals have argued that the slow recovery of that part of the city has had high social costs, and while there is no formal analysis of the impacts of a shortage of sections on the rate of recovery, preventing new building in the HFHMA on that side of the city is likely to exacerbate social problems in the short term.

7.5 A more detailed description of the analysis underlying these conclusions is contained in the report to Council which is attached as **Attachment B**.

8. LIMITATIONS OF MY ANALYSIS

8.1 Due to the tight timeframes for the analysis underlying this evidence, some information is not yet available. For example, a more detailed analysis of intermediate flood events associated with the Cashmere FPMA might lead to a significant change in the estimates of avoided damage. Nonetheless, the conclusions regarding the effects of the rules on rural land are believed to be robust and are unlikely to change. Estimate of changes in total flood damage, including those forms of damage which are not included in the model, would have to significantly fall, or estimates of marginal value of rural land would have to significantly rise, to change the current conclusion that the proposed FPMA rules for rural land in the Cashmere FPMA are appropriate.

8 As a recent project manager for a block of 40 sections in Awatea Rd, and as a trustee of the Community Housing Trust which is considering subdivision of land to provide affordable sections, I take a keen interest in the availability of completed sections and have regular conversations with developers, builders and real estate agents. I am aware that, for example, the proposed Highfields subdivision has not proceeded, that the subdivision adjacent to the Groynes was left in a partially completed state for some time because the developer was unable or unwilling to complete the development in the current market, and the partially completed subdivision off Yaldhurst Rd just north of Russley Road has remained apparently vacant for some time.

8.2 Further modelling runs which relaxed the rules on just the residential and business private land in the Cashmere FPMA, as opposed to all private land, would enable a more definitive answer to be given as to whether the proposed rules are appropriate for the residential and business land in the Cashmere FPMA.

8.3 The value of the HFHMA rules is much less certain. A very substantial modelling effort would be required to improve our understanding of the effects of the proposed rules, or alternative rules, in reducing property damage, injuries and death.

8.4 This analysis assumes that the community is risk neutral, whereas in fact there may be a significant level of risk aversion, particularly with regard to events which affect large numbers of people and where effects may include serious consequences such as personal injury or death. Risk aversion would shift the balance in favour of the proposed rules. Modification of these conclusions to reflect risk aversion is a political decision rather than an economic one, and is something on which I am unable to provide a professional opinion.

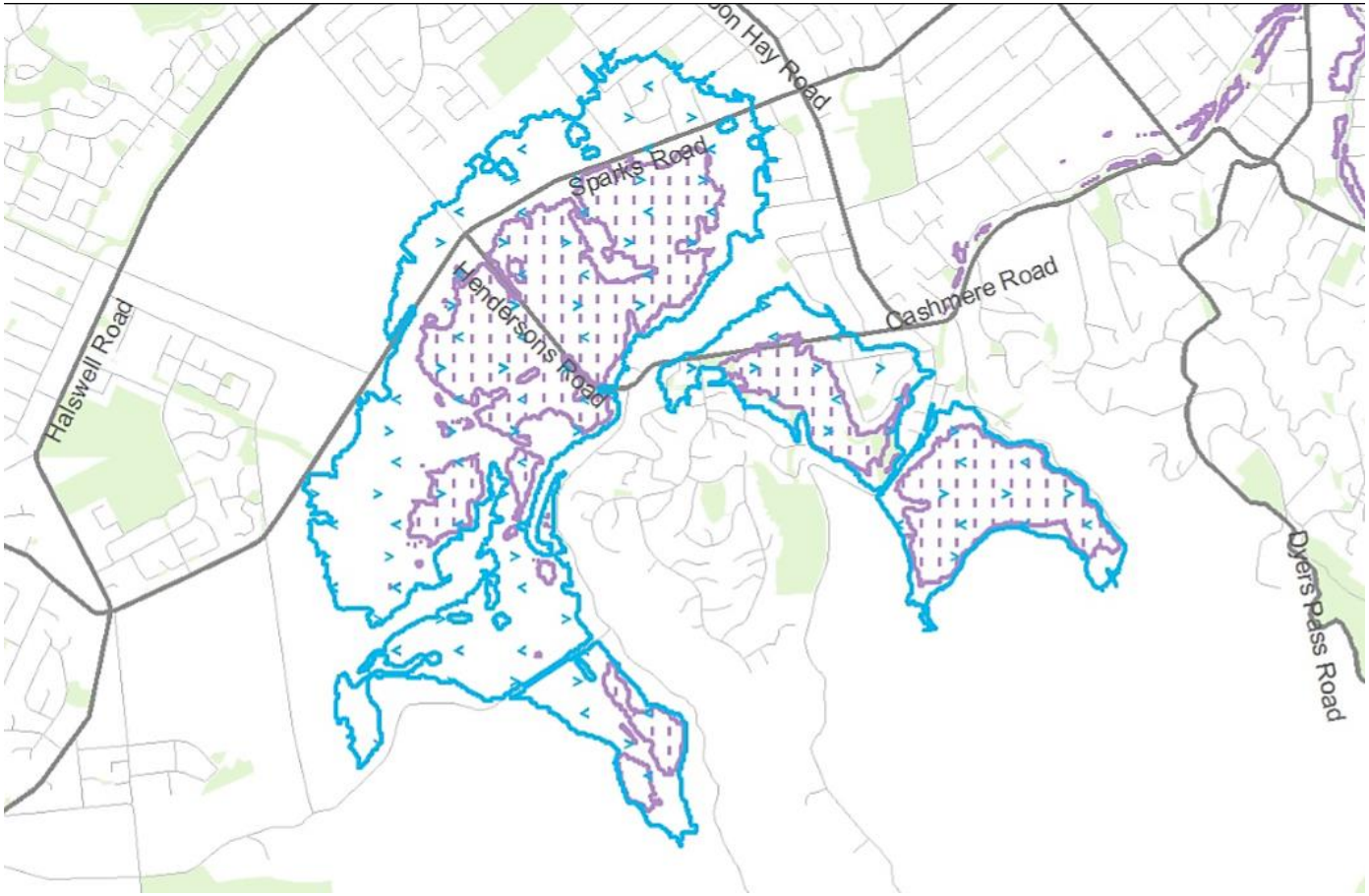
8.5 The current status of rules affecting development in Cashmere FPMA has led to the current outcomes for downstream properties. Relaxing those rules, and allowing subdivision and building as a result, would lead to benefits to landowners in the ponding area and costs to landowners downstream who are more likely to be flooded. Such development may not be permitted under the RMA, but that is not a matter which I have addressed in undertaking this analysis.

Geoffrey Vernon Butcher

21 January 2016

ATTACHMENT A – Flood Ponding and Flood Hazard Areas

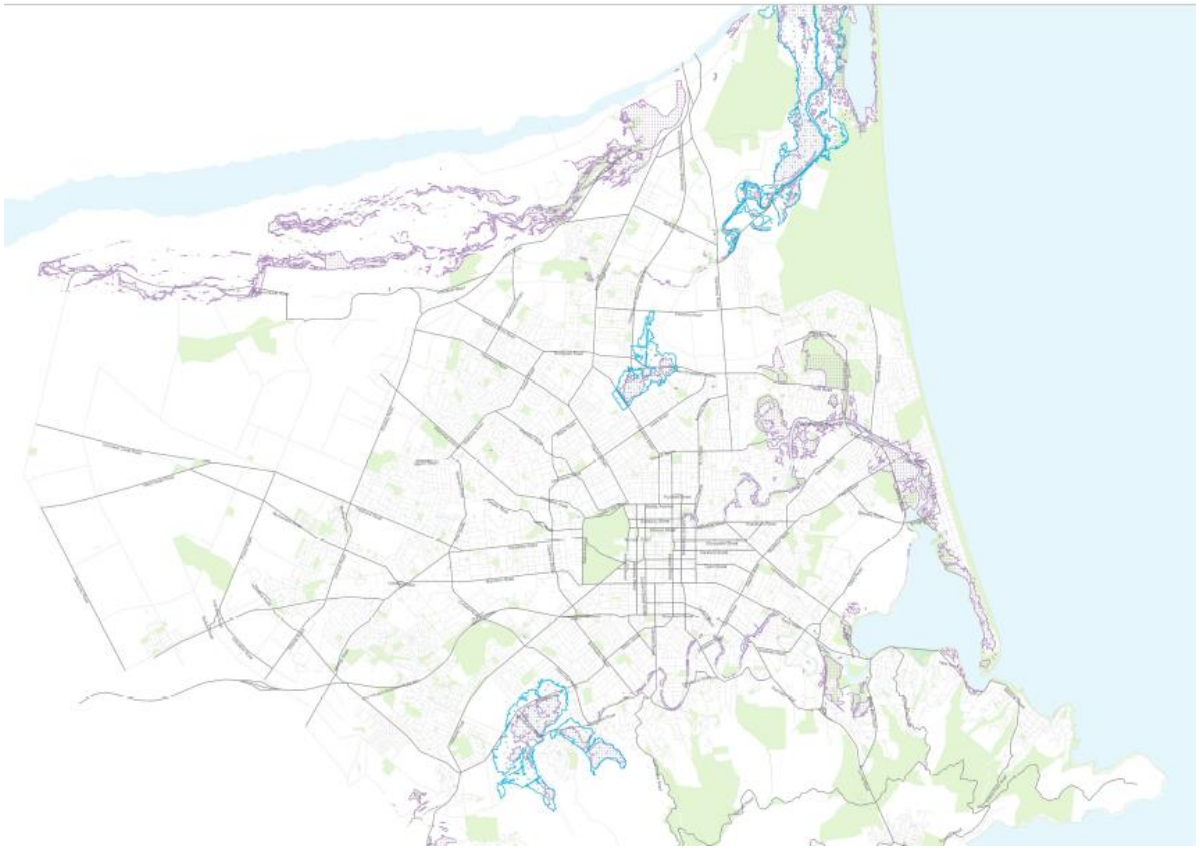
Figure 1. Hendersons – Cashmere – Detail of Hoon Hay FPMAs



The area coloured blue is FPMA

The area coloured purple is HFHMA

Figure 2. Overview of FPMAs and HFHMAs



The area coloured blue is FPMA

The area coloured purple is HFHMA

Attachment B – Report to Council of analysis underlying conclusions

Economic Costs and Benefits of Proposed Rules which Limit Development of land within identified Flood Ponding Areas and High Flood Hazard Area.

Butcher Partners Ltd: January 2016

1. Background:

The proposed Christchurch Replacement District Plan (pCRDP) has identified Flood Ponding Management Areas, which are intended to detain water in heavy rain events and in so doing reduce flooding downstream. The pCRDP also identifies areas which are at risk from Flood Hazard, and this is areas where in a one in 500 year event leads to a depth of water which exceeds 1m OR where the product of the depth of water (in metres) and the spend of the water flow (in metres / sec) exceeds 1.0. Note that flood depths were calculated under an assumed 1 m increase in sea levels and 16 % increase in rainfall depth arising from climate change.

Proposed rules in the pCRDP seek to make subdivision or new building in these areas Non-Complying Activities, which in broad terms means they will be very much discouraged with resource consent being difficult to achieve in most circumstances, and also expensive to achieve.

2. Scope of Work

CCC has asked BPL to review the effects that are anticipated from the implementation of the rules, including environmental, economic, social and cultural impacts as well as the opportunities for economic growth and employment that are anticipated to be provided or reduced. It was anticipated that the review would draw on information from earlier studies.

The original scope of work was intended to cover three broad ponding areas being:

- Hendersons Basin & Cashmere Stream Floodplain & Cashmere-Worsleys ponding area & Hoon Hay Valley ponding area (hereinafter called “Hendersons-Cashmere-Hoon Hay”;
- Lower Styx Ponding Area;
- Cranford Basin.

Cranford basin has been excluded from further analysis primarily because there is now a Notice of Requirement in place for purchasing the land from private owners, and hence the economic analysis has become redundant. Furthermore I am advised that the Cranford Basin is extremely complex to model in hydrological terms, and hence it would be difficult to assess likely damage arising if the Basin were allowed to be filled. Finally, it is understood that there have been significant changes of ground level in the areas likely to be most affected by the loss of ponding facility in the Cranford

Basin and the Riskscape model would need to be recalibrated for the post-earthquake changes in ground level before the financial costs flowing from the model would be meaningful.

Lower Styx Ponding has not been assessed because of the limitations of time. The theoretical process would be similar to the process involved in Hendersons Ponding Area, but hydrological modelling is not available for this area.

The work was also to consider the identified Flood Hazard Areas.

3. Physical Areas Involved

Table 1 shows the areas of land affected by the rules. This table includes only those parts of properties which are affected by the rules as opposed to the total areas of those properties. Some properties have land which is both in a Flood Hazard Zone and is subject to ponding. In those cases the area described as being in the Flood Hazard Zone excludes land which is also in a Flood Ponding area. Information on land areas was provided by the GIS division of Christchurch City Council.

Table 1. Physical Areas Affected by Rules (Ha)

	High Hazard Area	**Ponding Areas**		
	Ha (excl. ponding areas)	Henderson Ponding	Cranford	Lower Styx
BUSINESS	8.4	5.3	-	2.0
NON-RATEABLE	324.9	5.5	0.0	28.9
RESIDENTIAL	200.6	55.1	0.4	40.4
RURAL	267.0	299.4	27.9	134.4
Not -Specified	2.7	27.0	8.4	-
Total	803.6	392.4	36.6	205.7

4. General Approach to Estimating Whether the Rules Will Encourage Efficient Use of Resources

4.1 Flood Ponding Basins

The benefit of retaining land for ponding and preventing development for other purposes such as housing is that flooding downstream is reduced. The cost of using land for ponding is that it prevents use of the land in the basin for other purposes of potentially greater value, including residential development. If the benefits of reduced flooding exceed the costs of preventing alternative use of the land, then the rules are likely to encourage efficient resource use.

It may be that there is a cheaper way of reducing flooding than using ponding basins. For example, it may be possible to increase spending on other engineering works to manage flooding to the same degree.

The cost of preventing development would be based on the difference in value between land in the ponding area for which uses are restricted by the rules, and similar land which is not restricted by

such rules. In the case of Henderson's Basin this difference in value can conveniently be assessed by comparing the Rating Valuation of blocks of land within the ponding area and blocks of adjacent land. The difference in land value may also be due to underlying differences in the suitability of the land for subdivision purposes, and in this regard it should be recognized that by definition the land in the ponding area is lower-lying and would need to be built up with greater levels of fill than would adjacent land. Hence the differences in land value will over-state the difference in value caused by the existing rules. On the other hand the difference in land value may not yet fully reflect the rules because the rules are not yet in place. However, existing rules have similar impacts to the proposed rules, and so existing values probably reflect reasonably well the land value under the proposed rules.

4.1.1 Are Rules Appropriate for Ponding Areas

Rules are an appropriate means of managing Flood Ponding areas because the people who benefit from the prevention of flooding are not the same as the people who pay the costs of being prevented from developing their land. Agreement between the two groups and the payment of financial or other compensation is not practical, and an effective outcome is most likely to be achieved by Rules.

4.2 Flood Hazard Zones

The proposed rules for High Flood Hazard Areas stipulate that subdivision and new buildings are non-complying activities. These are areas in which in a 500 year event there is expected to be at least 1.0 m of water OR the product of water depth in metres and water velocity in metres / sec exceeds 1.0. The models assumed that sea levels would be 1m above current levels and rainfall depths would be 16 % above current depths as a result of climate change.

The rules seek to prevent damage to buildings and to injury or death in flood events. In principle an efficiency analysis (section 32) would compare the actions of people WITH the rules and the actions of people WITHOUT the rules, and compare the costs and benefits in the two cases.

Analysis should compare the likely benefits of preventing flood damage and potential loss of life in Flood Hazard Areas to the cost associated with preventing subdivision of or building on the land. This cost is equivalent to the value of the land for building in areas not prone to floods as opposed to the value in its next best use, which is possibly for urban parks or some form of agricultural production. Note that the comparison should not be between the costs of flood damage and the benefit of the difference between the market value of the flood-prone land for building and for alternative uses. This is because the market value of the flood-prone land will already have been adjusted downwards to reflect the known probability of flooding and the expected costs to the land owner of this – whether by higher insurance premiums, higher repair bills for uninsured items, and the intangible costs of living in a flood-prone area.

Alternatives to the proposed rules include implementing a minimum floor height to avoid the majority of physical flood damage, but the effects of this on reducing risks of death and injury would also need to be taken into consideration.

4.2.1 Are Rules Appropriate for Flood Hazard Zones

Usually rules are justified where there are externalities, which is to say where the people who benefit from their actions do not suffer the costs of their actions. In general one would expect that people who build in Flood Hazard Zones will get the benefits associated with cheaper land in these areas and would meet the costs of higher flood damage in these areas, with these higher costs being realized either by actual repairs or by higher insurance premiums compared to other areas. Hence there is no externality and no case for restrictive rules.

However, rules may also be justified even where there is no obvious externality if it is felt that the general public are not aware of the true extent of likely flood damage costs, or if it is felt that the internalized costs will be externalized by property owners trying to transfer the flood damage costs to the wider public through the political process by compensation for damage or by the construction of publicly funded preventive measures such as stop banks.

A powerful example of this externalizing of costs has been evident in Christchurch recently where it has been decided that the long-term costs of damage in the Red Zone are higher than residents can reasonably meet or higher than the council is prepared to meet, and so the residents have been compensated by the community as a whole. In some areas there was no real understanding that the potential for damage was so high, while in other cases the land was developed in spite of technical advice that the land had a high liquefaction risk. In the latter case this technical advice was ignored by developers and by the general public who purchased the land without being aware of this advice.

Data from Christchurch City Council indicates that there are 6,390 residential properties, of which 1,340[9] have an area greater than 900 m^2 and are potentially sub-divisible under council zoning rules requiring a minimum section size of 450 m2. Moreover of the 6,390 sections, 3,400 have improvements worth less than $10,000 implying that they do not currently have a house on them and under the new rules they would not be able to be built on. The proposed rules impose a potentially high cost on such properties. The rules also affect 153 business properties, 15 of which have improvements which exceed $1 million in value, implying that the rules apply to some valuable properties, and 100 of which have improvements which are worth less than $10,000 which again implies that they are vacant lots which cannot be built on under the proposed rules.

5. Who Suffers the Costs of the Rules

In general, rules impose costs which accrue to those who own the land at the time the rules are imposed.

If the rules prohibit activities which people would not want to undertake anyway (e.g. building in areas where floods are frequent) then the rules have no costs.

If the rules prohibit activities which people wish to undertake in spite of a full knowledge of the costs, then the rules have a net cost on those people and this cost is met by the land owners at the time the rules are imposed. Subsequent landowners do not suffer any costs since they will have purchased the land at a discount which reflects the existence of the rules.

There will be occasions when rules do not impose an actual cost on the community (e.g. where the expected costs of damage exceed the difference in land values between land available for building

9 658 if the area excludes that part of the section which lies within a ponding area

and land available only for the next best use such as parks), but where roles impose a perceived cost because people do not believe that the costs exceed the benefits. In such cases the perceived cost of the rules accrues to the current landowners.

Finally, where the rules exist because of externalities, then the costs are imposed on the owners of the land where activities are restricted. The cost accrues to the owners at the time the rules are imposed. The benefits accrue to the owners of the downstream flood-prone land at the time the rules are imposed. Subsequent owners will not get the benefit because the price of the property will have risen to reflect the benefit.

Since the proposed rules applying to flood hazard zones are new rules, then the cost will be borne by current owners. To the extent that proposed rules applying to flood ponding areas replace rules which have been in place for some time, the costs have already accrued to the owners of the land at the time those earlier rules were put in place. To the extent that the proposed rules extend existing rules, then the costs of the extension accrue to the current owners of the land.

Note that this analysis of who suffered the loss does not alter the size of the loss suffered by the community as a whole.

6 Costs and Benefits

6.1 Available Information

A review of available information revealed that while there is considerable information on the extent of potential flooding in Christchurch[10], there is little on the costs of flood damage in Christchurch. A 2008 paper by Harris[11] provided information on flood damage costs for various depths of water in houses and some relationship between building damage costs and other costs. It could potentially be used in an analysis of flood damage in the absence of ponding areas, but it would first require analysis of changes in water depth with and without the flood ponding areas for various flood events, and determination of the number of houses affected and the depth of inundation in each case. This is a major exercise which would be both expensive and impossible to complete in the available time. Fortunately there is now available a NIWA-developed and operated model called RiskScape. Amongst other things the RiskScape model estimates flood damage costs for various depths of water.

6.2 Ponding Areas

6.2.1 Property Damage related to Hendersons-Cashmere-Hoon Hay Ponding Area

The floodwater depths in the downstream areas affected by Hendersons-Cashmere-Hoon Hay Ponding area were provided from hydrological models run by DHI Group. The depths were estimated for three flood events (10 year, 50 year and 200 year) and for two states of land in the ponding area. In the first land state the rules were in place and no development has taken place. In

10 See for example GHD reports: Stormwater modelling consolidation final reports - Styx, Avon and Heathcote River models status reports, 2012 -2014

11 Harris, S. Climate Change Case Study: Assessment of the Impacts of Sea Level Rise on Floodplain Management Planning for the Avon River. For CCC 2008

the second land state, land not owned by council is assumed to be developed over time and to not be available for storage of flood waters[12].

The Riskscape model took those depths and calculated the costs of asset (building) repairs, contents (including vehicle) repairs and replacement, cleanup costs, and disruption costs. The model does not include other significant costs associated with flooding[13], and damage estimates are based on the location of buildings and floor heights pre-2011 earthquakes. There are also psychological costs associated with the risk of flooding threats even when flooding does not occur.

6.2.2 Reductions in Land Values in Henderson-Cashmere-Hoon Hay Ponding Area

Information was obtained from the Christchurch Rates data base on the land value of rural land in the Hendersons-Cashmere-Hoon Hay ponding area, and rural land adjacent to the ponding area. The difference per Ha is expected to be due to a mix of lower land quality and, more importantly, an inability to subdivide land at some later date for residential purposes[14]. While rural land adjacent to the ponding area is not zoned for residential development, it is within the urban boundary and is likely to be able to be zoned in the comparatively near future.

6.3 Flood Hazard Zone

All that is known about the Flood Hazard Zones is the total area, by Land Use, that has been so zoned, and the fact that modelling has identified that the land is susceptible in a 500 year flood event to a flood depth of at least 1.0m, or a depth in metres multiplied by flow velocity in metres / sec of at least 1.0. It is not possible to estimate likely damage to houses either in the 500 year event OR in more frequent events. This is because many of the sections are already vacant and to specify a likely floor level of a new building would be pure speculation.

A rough approximation of the rule cost can be made on a per section basis, with this difference being the difference between land value for housing and for an alternative use.

An alternative rule which would raise floor levels and reduce flood damage can be costed and compared to the loss of land values. The two costs are not directly comparable in that they have different outcomes in terms of damage avoided, particularly for personal injury and death from flood waters which may still occur even if floor levels are raised.

7. Results and Conclusions

7.1 Hendersons-Cashmere-Hoon Hay Ponding Area

7.1.1 Benefits from Reduced Flood Damage Costs

Estimates of damage produced by the RiskScape modelling of DHI Group water depth modelling of various events for the two land states are shown in the second column of Table 2. The private land

12 In both states the land in Hoon Hay Valley and south of Cashmere Rd, and land south of Worsleys road was assumed to be available for ponding.

13 For example, death and injury, damage due to scouring in areas of high flow velocity, need for traffic to divert from flooded streets, non-remunerated personal effort involved by affected households.

14 While rural land adjacent to the ponding area is not zoned for residential development, it is within the urban boundary and is likely to be able to be zoned in the comparatively near future

which was deemed to be available for ponding in one Land state and not the other totaled around 60 Ha of residential and Business Land and 200 Ha of rural land.

The annual damage is calculated using a standard modelling process which in effect gives an approximation of the area under the damage probability curve.

Table 2. Damage of Various Flood Events and Estimated Difference in NPV with Ponding and Without Ponding (NPV $m)

	A Damage for event ($000) RiskScape	B Annual Prob of Exceedance	$C = B^{e-1}-B^{e}$ Difference in probability	$D = (A^{e}+A^{e-1})/2$ Average damage over interval ($000)	E = C x D Ave Annual Cost ($000 / yr)
With Ponding					
0 yr event	0	1.00000			
10 yr event	2,031	0.10000	0.900	1,015	914
50 yr event	25,449	0.02000	0.080	13,740	1,099
200 yr event	66,016	0.00500	0.015	45,733	686
Ultimate event*	330,080	0	0.005	198,048	990
TOTAL					**3,689**
Without Ponding					
0 yr event	-	1.00000			
10 yr event	3,325	0.10000	0.900	1,662	1,496
50 yr event	32,577	0.02000	0.080	17,951	1,436
200 yr event	89,243	0.00500	0.015	60,910	914
Ultimate event*	446,213	0	0.005	267,728	1,339
TOTAL					**5,184**
Difference					
0 yr event	-	1.00000			
10 yr event	1,294	0.10000	0.900	647	582
50 yr event	7,128	0.02000	0.080	4,211	337
200 yr event	23,227	0.00500	0.015	15,177	228
Ultimate event*	116,133	0	0.005	69,680	348
TOTAL					**1,495**
NPVs				100 yrs	200 yrs
7 %				$21 m	$21 m
5 %				**$30 m**	**$30 m**
3 %				$47 m	$50 m

* The cost of an "Ultimate event" is assumed to be 5 times the cost of a 200 year event. Changing the factor from 2 to 20 changes the NPV damage from a Base Case $30m to $26 million in the former case and $35 million in the latter case

The difference in expected Annual Damage ($1.495 million per year) is shown towards the bottom of the table, and this annual damage is converted to a Net Present Value under various terms and discount rates at the bottom of the table. The Difference in NPV of damage under the two states of nature is $30 million at a 5 % discount rate[15] over 100 years. Approximately $23[16] million of this is associated with ponding on rural land and $7 million with ponding on residential and business land.

15 A 5 % discount rate is believed to be appropriate in this context. While Treasury currently uses a discount rate of 7 % for infrastructure projects, there are strong arguments in favour of a lower discount rate for projects such as

7.1.2 Costs of Reduced Opportunities for Land Use

Values per Ha for "marginal land over and above the house site" were estimated for rural properties close to and within the Hendersons-Cashmere-Hoon Hay ponding area by:

- Taking the rateable land value and deducting $200,000 as the value of a basic section to give the value of the marginal land;
- Taking the rateable land area and deducting 1,000 m^2 as the area of a basic section to give the area of the marginal land;
- Dividing the value of the marginal land by the area of the marginal land to get a value per Ha for marginal land.

For 42 sites close to the ponding area the value per Ha was $275,000 whereas for the 11 sites within the ponding area the value per Ha was $125,000, a difference of $150,000.

The difference in value of land arises from a combination of differences in land quality at the two sites (for both its current use as lifestyle blocks and its potential future use for subdivision) and the rules which prevent subdivision and building in the Basin sites. The value of land within the Basin will be lower for lifestyle purposes because of flooding risks, and lower for future subdivision purposes because more fill will be required to create house sites compared to land outside the Basin. It is also possible that soil geology will be poorer within the Basin which will increase construction costs for services and building and hence further reduce the comparative value of the land within the Basin for subdivision purposes. Hence some of the land value difference between land in the Basin and land out of the Basin will be due to the natural character of the land. The rest of the difference in land values will be due to the rules.

While the $150,000 per Ha difference in value for land cannot be allocated with certainty between land quality and rules, on balance it seems likely that the impact of the rules will be to reduce rural land values by a maximum of $100,000 per Ha, and possibly significantly less. Using the figure of $100,000 per Ha, the proposed rules would reduce by approximately $20 million the value of the approximately 200 Ha of private rural land in the Basin which was included in the comparative damage analysis. The figure of $20 million is a likely upper limit to this value.

7.1.3 Conclusions regarding Rules for Hendersons-Cashmere Hoon Hay Ponding Area

The results suggest that the benefits associated with rules which maintain this ponding ability are approximately $30 million of identifiable damage costs plus considerable unidentifiable costs. At least $23 million of this benefit is associated with rural land, which is more than the $20 million cost associated with restricting the use of rural land. The conclusion is that the proposed rules will lead to efficient use of resources with regard to rural land in the basin.

The position with regard to the proposed rules as they apply to residential and business land is less clear. There is approximately 60 Ha of such land, comprising 13 business and 626 residential properties. Of these properties, 10 are vacant and under the proposed rules they could not be built on, while 237 are greater than 800 m2 and hence potentially suitable for subdivision which would

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Hendersons Basin. A lower rate reflects a "Social Rate of Time Preference", and may also be consistent with the discount rate implicit in the land values with which these flood damage costs are being compared. Land values reflect the discount rates required by those investing in land for future development. See NZIER *Insight* no. 32/2011 for a discussion of the issues surrounding discount rates.

16 60 Ha of business and residential land and 200 Ha of rural land changes state. $30m x 200 / (200+60) = $23m. This assumes that ponding depths are the same on average over all land type. Ponding may be deeper on rural land, which would increase the damage associated with rural land and reduce that with other land.

not be permitted under the rules. The rules will impose significant costs on those properties for a benefit which is approximately $7 million[17], but may be considerably less than this[18]. If the cost of the rules exceed $8,000 - $16,000[19] per residential property, then the rules will not lead to an efficient use of resources. Further analysis of the effects on downstream flood damage of removing ponding storage on these properties, and further analysis of the benefits to residential and business properties of removing the rules, is warranted.

7.1.4 Effects on other Social, Environmental and Cultural Outcomes

The proposed rule will prevent rebuilding on a small number of residential properties which are currently vacant, and will prevent subdivision and subsequent building on a further 100 – 200 properties. This increased section supply will have some small impact on the price of sections in this part of town, but it will not be significant because the Christchurch property sub-markets are strongly related and the 200 affected properties are equivalent to less than 0.1 % of residential properties in Christchurch.

It is unlikely that the proposed rules will materially affect opportunities for economic growth and employment. There have been numerous subdivisions completed in Christchurch since the earthquakes, and a number of commentators now believe that there is, if anything, an excess supply of sections available. Reducing the number of buildable sections in Flood Hazard and Ponding zones is unlikely to materially affect rates of economic activity in residential construction.

The retention of rural land in its current form in the ponding area may provide some environmental benefits, but the benefits are not known. There is likely to be little benefit from the retention of farmland per se, except to the extent that the ponding areas become wetland and offsets the huge loss of wetland habitat in Canterbury within the last 150 years.

7.2 Flood Hazard Areas

7.2.1 Benefits from Reduced Flood Damage and Reduced Injury or Death.

It has not been possible to estimate reductions in flood damage, or personal injury or death costs arising from the proposed rules preventing subdivision and building in Flood Hazard Zones. Information on this is likely to come out of a more substantial piece of work which CCC is currently pursuing. Work by Harris in 2008 suggested that the cost per house of flooding to a depth of > 1.0m is $100,000[20]. While the Flood Hazard Zones reflect areas where water will be at least this deep in a 500 year event, this single costs tells us little about the water depths in more frequent events which quite commonly are the primary driver of annual average flood damage costs. Hence at this stage it is not possible to assess the benefits of the proposed rules in terms of reduced flood damage.

17 The calculated benefit is $7 million, but it will be less than this if, as seems likely, the residential and business properties are higher land and hence have less ponding capacity / Ha on average than do the rural properties. On the other hand, calculated property damages understate total damages and so the benefits of permitting ponding on residential and business land may exceed the calculated benefits.

18 The effect of section development on damage costs assume a loss of ponding equivalent to the entire section being built up with fill. If only the building platform were built up, then the effects would be less.

19 $5 million to $10million spread over approximately 640 properties.

20 Harris quotes figures of $41,600 for repairs to the house and $47,500 to chattels. Combining these figures and adjusting for inflation gives a total of $101,000.

There is little information available on the number of people likely to be killed or injured in a flood event of the 500 year magnitude, let alone in lesser events which, typically, produce the large component of flood damage costs[21]. One could postulate a value per life of $3 million and costs of injury being some proportion of that, but lack of data precludes a sensible assessment of the annual cost equivalent. If there was sufficient information available on the benefits of reduced physical damage and the costs of reduced opportunities for land use (see below), then one could assess the required impact of the proposed rules on the probability of death and injury in various flood events for the proposed rules to lead to efficient use of resources.

7.2.2 Costs of Reduced Opportunities for Land Use

A very approximate value of a developed section in the Flood Hazard Zone is $100,000[22]. The figure is highly dependent on the geological conditions which affects the foundation costs, and a significant portion of the Flood Hazard zone in in the Red Zone which has particularly poor ground conditions. A figure of $100,000 seems consistent with an assumption that flood-prone areas often have poor ground conditions.

It is difficult to assess the value of this land to the community for the purposes of recreation. Prior to the establishment of the Red Zone the existing sections were already serviced by parks and reserves which were presumably deemed sufficient for the needs of the existing community and further reserves may have limited value. Moreover, the marginal value of recreation land will presumably decrease as more of the Red Zone / Flood Hazard Area is re-purposed as recreation land. The land may have a higher non-residential value use than purely recreation if it is used to treat stormwater run-off prior to this entering the river systems.

If a typical section has a value of $20,000 in the next best alternative use, then the cost of the rule is approximately $80,000 per section.

7.2.3 Costs of Alternative Rule with a lesser reduction in land use

A rough order of magnitude is that raising the floor level by 1.0 metres will typically cost around $15,000 - $25,000[23] per site, although this will depend hugely on the geology of the individual site and on the type of floor that the house is to be built with. On this basis, it seems likely that a rule which permits building provided it is above some minimum floor level is a preferable rule to the proposed rules which make construction of new houses a non-complying activity.

To establish the suitability of this alternative rule would require an understanding of its effect on death and injury.

7.2.4 Conclusions regarding Rules for Flood Hazard Zones

There is insufficient information regarding the potential for avoiding flood damage in this zone to indicate whether the proposed rules preventing subdivision and building in Flood Hazard Zones is

21 Riskscape software apparently has a routine for calculating death and injury in relation to flooding. The adequacy of this for assessing the loss in the Flood Hazard Area has yet to be established.
22 Council has been asked to provide rateable land value information for properties in the Flood Hazard Zone.
23 Placed and compacted fill costs perhaps $60 - 80 / m3, and a 150 m2 house will require a raised footprint of perhaps 200 m3 at a cost of around $15,000. A cheaper alternative is likely to be a house on higher piles.

likely to lead to a more efficient use of resources. Formal economic justification of the rules would require substantial research on the depth of water under various flood events, the levels of property damage, and likely levels of death and injury in these events.

It is possible that a more effective means of achieving the objective of minimizing flood damage would be a rule specifying minimum floor heights. While this would not prevent potential injuries or deaths arising from people being in deep or fast-flowing water, it will presumably reduce them, and it may be that the risks are judged to be sufficiently low to be acceptable.

7.2.5 Effects on other Social, Environmental and Cultural Outcomes

The proposed rule will prevent some thousands of properties being rebuilt on. This is likely to increase the price of sections in this part of town, or at least stop them falling. While the approximately 6,000 affected residential properties are less than 3 % of total Christchurch properties, the 3,400 properties which are currently vacant is a significant number in terms of long term average demand for sections and could materially affect prices. The potential impacts on section prices are even greater when one notes that more than 1,300 of these residential sections are 900 m2 or more and would be readily subdivisible under existing subdivision rules. The number of potential sites under more liberal subdivision rules which are likely in future is obviously considerable greater, making it even more likely that the proposed rule will have a noticeable effect on section prices in the area.

The financial losses arising from the proposed rules, particularly those relating to residential areas, are likely to fall to a significant extent on central government as owner of the Red Zone land, which encompasses a significant proportion of the residential land in High Flood Hazard areas.

It is unlikely that the rules will materially affect opportunities for economic growth and employment. There have been numerous subdivisions completed since the earthquakes, and a number of commentators now believe that there is, if anything, and excess supply of sections. Reducing the number of buildable sections in Flood Hazard and Ponding zones is unlikely to materially affect rates of economic activity in residential construction. The only concern is that the sections which are in the Flood Hazard Zone include a significant number that have, historically, been in medium to low income areas, whereas most of the new subdivisions have more expensive sections. On the other hand, many of the sections in the Flood Hazard zones are likely to require more expensive foundations than are sites on firmer and higher ground, so the price advantages may be less than it seems at first glance.

Flood Hazard Zones and a consequential reduction in section availability in the east of Christchurch may hamper recovery of the community on that side of town. Numerous individuals have argued that the slow recovery of that part of the city has had high social costs, and while there is no formal analysis of the impacts of a shortage of sections on the rate of recovery, preventing new building in the Flood Hazard Zone on that side of the city is likely to exacerbate social problems in the short term.

The development of large urban parks on former residential land will provide some environmental benefits, but there is no evidence as to how significant these will be. Anecdotal evidence is that there is already a wider range of bird-life in the Red Zone area.

8. Limitations to This Analysis

The foregoing analysis has been completed in some haste and with some information simply not being available. More detailed analysis of intermediate flood events associated with Hendersons-Cashmere-Hoon Hay Basin might lead to a significant change in the estimates of avoided damage. Nonetheless, the conclusions regarding the effects of the rules on rural land are believed to be robust and are unlikely to change. Estimate of changes in total flood damage, including those forms of damage which are not included in the model, would have to significantly reduce, or estimates of marginal value of rural land would have to significantly increase, to change the current conclusion that the proposed rules for rural land in the basin are appropriate.

Further modelling runs which relaxed the rules on just the residential and business private land in the Basin, as opposed to all private land, would enable a more definitive answer to be given as to whether the proposed rules are appropriate for the residential and business land in Hendersons Basin.

The value of the rules on Flood Hazard Zones is much less certain. A very substantial modelling effort would be required to improve our understanding of the effects of the proposed rules, or alternative rules, in reducing property damage, injuries and death. This analysis assumes that the community is risk neutral, whereas in fact there may be a significant level of risk aversion, particularly with regard to events which affect large numbers of people and where effects may include serious consequences such as personal injury or death. . Risk aversion would shift the balance in favour of the proposed rules.

NZCPS references.

Policy 3: Precautionary approach

In the "*New Zealand Coastal Policy Statement 2010*"

1. Adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.
2. In particular, adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change, so that:
    a. avoidable social and economic loss and harm to communities does not occur;
    b. natural adjustments for coastal processes, natural defences, ecosystems, habitat and species are allowed to occur; and
    c. the natural character, public access, amenity and other values of the coastal environment meet the needs of future generations.

Policy 7: Strategic planning

In the "*New Zealand Coastal Policy Statement 2010*"

1. In preparing regional policy statements, and plans:
    a. consider where, how and when to provide for future residential, rural residential, settlement, urban development and other activities in the coastal environment at a regional and district level; and
    b. identify areas of the coastal environment where particular activities and forms of subdivision, use, and development:
        i. are inappropriate; and
        ii. may be inappropriate without the consideration of effects through a resource consent application, notice of requirement for designation or Schedule 1 of the Resource Management Act process; and provide protection from inappropriate subdivision, use, and development in these areas through objectives, policies and rules.
2. Identify in regional policy statements, and plans, coastal processes, resources or values that are under threat or at significant risk from adverse cumulative effects. Include provisions in plans to manage these effects. Where practicable, in plans, set thresholds (including zones, standards or targets), or specify acceptable limits to change, to assist in determining when activities causing adverse cumulative effects are to be avoided

Policy 24: Identification of coastal hazards

In the "*New Zealand Coastal Policy Statement 2010*"

1. Identify areas in the coastal environment that are potentially affected by coastal hazards (including tsunami), giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, are to be assessed having regard to:
    a. physical drivers and processes that cause coastal change including sea level rise;
    b. short-term and long-term natural dynamic fluctuations of erosion and accretion;
    c. geomorphological character;
    d. the potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent;
    e. cumulative effects of sea level rise, storm surge and wave height under storm conditions;
    f. influences that humans have had or are having on the coast;
    g. the extent and permanence of built development; and
    h. the effects of climate change on:
        i. matters (a) to (g) above;
        ii. storm frequency, intensity and surges; and
        iii. coastal sediment dynamics;

    taking into account national guidance and the best available information on the likely effects of climate change on the region or district.

Policy 25: Subdivision, use, and development in areas of coastal hazard risk

In the "*New Zealand Coastal Policy Statement 2010*"

In areas potentially affected by coastal hazards over at least the next 100 years:

a. avoid increasing the risk[10] of social, environmental and economic harm from coastal hazards;
b. avoid redevelopment, or change in land use, that would increase the risk of adverse effects from coastal hazards;

c. encourage redevelopment, or change in land use, where that would reduce the risk of adverse effects from coastal hazards, including managed retreat by relocation or removal of existing structures or their abandonment in extreme circumstances, and designing for relocatability or recoverability from hazard events;
d. encourage the location of infrastructure away from areas of hazard risk where practicable;
e. discourage hard protection structures and promote the use of alternatives to them, including natural defences; and
f. consider the potential effects of tsunami and how to avoid or mitigate them

Policy 26: Natural defences against coastal hazards

In the "*New Zealand Coastal Policy Statement 2010*"

1. Provide where appropriate for the protection, restoration or enhancement of natural defences that protect coastal land uses, or sites of significant biodiversity, cultural or historic heritage or geological value, from coastal hazards.
2. Recognise that such natural defences include beaches, estuaries, wetlands, intertidal areas, coastal vegetation, dunes and barrier islands

Policy 27: Strategies for protecting significant existing development from coastal hazard risk

In the "*New Zealand Coastal Policy Statement 2010*"

1. In areas of significant existing development likely to be affected by coastal hazards, the range of options for reducing coastal hazard risk that should be assessed includes:
    a. promoting and identifying long-term sustainable risk reduction approaches including the relocation or removal of existing development or structures at risk;
    b. identifying the consequences of potential strategic options relative to the option of "do-nothing";
    c. recognising that hard protection structures may be the only practical means to protect existing infrastructure of national or regional importance, to sustain the potential of built physical resources to meet the reasonably foreseeable needs of future generations;
    d. recognising and considering the environmental and social costs of permitting hard protection structures to protect private property; and

    e. identifying and planning for transition mechanisms and timeframes for moving to more sustainable approaches.
2. In evaluating options under (1):
    a. focus on approaches to risk management that reduce the need for hard protection structures and similar engineering interventions;
    b. take into account the nature of the coastal hazard risk and how it might change over at least a 100-year timeframe, including the expected effects of climate change; and
    c. evaluate the likely costs and benefits of any proposed coastal hazard risk reduction options.
3. Where hard protection structures are considered to be necessary, ensure that the form and location of any structures are designed to minimise adverse effects on the coastal environment.
4. Hard protection structures, where considered necessary to protect private assets, should not be located on public land if there is no significant public or environmental benefit in doing so.

75 Contents of district plans

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(3) A district plan must give effect to—

(a) any national policy statement; and

(b) any New Zealand coastal policy statement; and

(c) any regional policy statement.

185 Rocking Horse Road Property Search Results

For the selected property this map shows the relevant planning zone, and any overlay that may apply. Click on the relevant zone name or any overlay for more details.

Other Notations

Coastal Environment
Coastal Environment

Natural Hazard Overlays

Flood Hazard Management
High Flood Hazard Management Area

Information Only

Zone
Stage 1 and 2

Click here to view the planning map for this area.

Coastal Land Use Zone:
C Coastal

Specific Purpose Land Use Zones:
SPLR Specific Purpose Flat Land Recovery

Natural and Cultural Heritage

Heritage Item
Heritage Item (Please refer to the Heritage Item Schedule)

Heritage Setting
Heritage Setting

Significant Trees
Significant Tree

Ecological Significance
Sites of Ecological Significance

Coastal Landscape
Area of at least High Natural Character in the Coastal Environment

Natural Landscape
Outstanding Natural Feature or Landscape

Natural Landscape
Significant Feature or Landscape

Other Notations

Waterway
Downstream Waterway (Mona Vale)
Downstream Waterway
Upstream Waterway
Environmental Asset Waterway

Coastal Environment
Coastal Environment

Natural Hazard Overlays

Flood Hazard Management

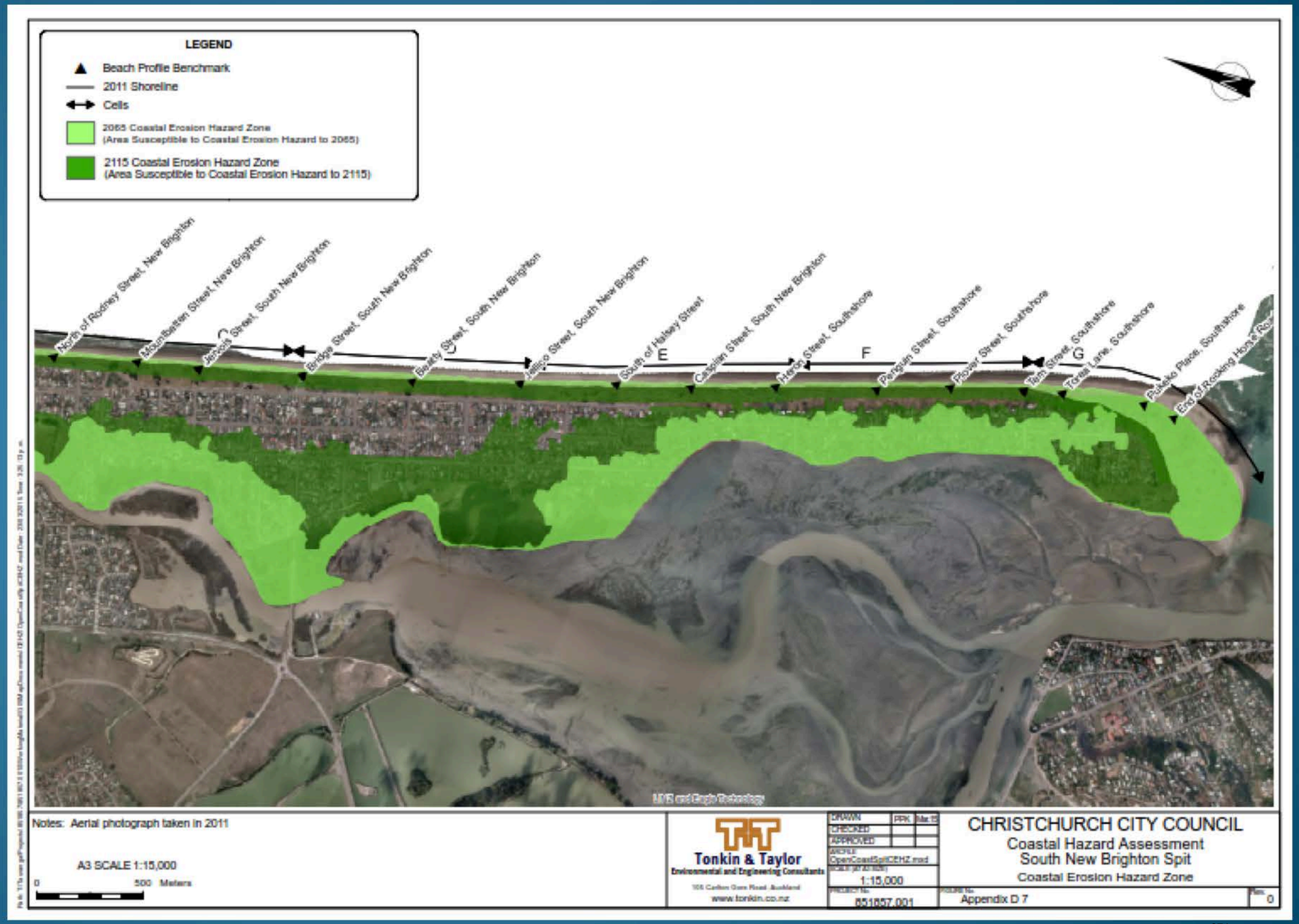
Coastal Erosion

Map example:

South New Brighton Spit

2065

2115



Coastal Inundation

Map example: Avon-Heathcote Estuary

2065

2115