MOKIHINUI HYDRO PROPOSAL
CONSENT APPLICATIONS
REVIEW OF ASSESSMENT OF EFFECTS OF DAM ENGINEERING

JULY 2008

Prepared by:
Peter F Foster

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1.0 Introduction

1.1 Background

This report provides a review of the assessment of environmental effects (AEE) provided by Meridian Energy Ltd (Meridian) in support of resource consent applications to dam the Mokihinui River associated with the Mokihinui Hydro Proposal (MHP).

This report will provide the decision-maker with information and advice related to dam safety issues and the associated effects of a hypothetical dam breach, which is a potential effect of low probability which has a high potential impact. It should be read in association with the report of Mr Don Tate which covers engineering issues more generally but reaches similar conclusions.

1.2 Qualifications

My name is Peter Francis Foster. I have been employed by MWH New Zealand Ltd (MWH) as a Senior Civil/Hydro Engineer since 2002. Prior to that I was employed by the Ministry of Works and Development, Works Consultancy Service and Opus International Consultants. My qualifications are Bachelor of Engineering (Honours) from Canterbury University. I am a Member of the Institution of Professional Engineers, New Zealand and a Chartered Professional Engineer.

My area of expertise is dam engineering. I was a member of the design team for the 102 m high Clyde dam, and my responsibilities included designing remedial works to the dam foundations, stability analysis of the dam under static and seismic loads and instrumentation of the dam. I am a past Chairman of the New Zealand Society on Large Dams (NZSOLD), and contributed to the preparations of their November 2000 revision of the New Zealand Dam Safety Guidelines. I am a technical advisor to the Department of Building and Housing on issues related to the Dam Safety provisions of the Building Act 2004, its Amendment (2008) and associated Regulations.

In the last 5 years I have completed comprehensive safety reviews on 6 large dams owned by either Watercare Services or Mighty River Power, and I undertake annual inspections and safety reviews of Clyde and Roxburgh dams for Contact Energy. I am also serving as a dam engineering expert on two review panels for concrete dam remedial works projects in Australia and am on an expert panel reviewing the Australian National Committee on Large Dams (ANCOLD) Concrete Gravity Dam Guidelines.

1.3 Code of Conduct Statement

I, Peter Francis Foster, have read and understand the Code of Conduct for Expert Witnesses issued by the Environment Court in March 2005. The evidence presented is within the dam engineering area of expertise, except where stated that reliance has been on information provided by another technical specialist. I have not knowingly omitted facts or information that might alter or detract from the opinions expressed.

1.4 Scope of Report

This report is prepared under the provisions of Section 42A of the Resource Management Act 1991 (RMA).

To carry out this review of the consent application I have considered the relevant sections of the AEE submitted by Meridian, and the following technical appendices:

- Damwatch (2007) Mokihinui Hydro Proposal Project Engineering Description
- NIWA (2007) Mokihinui River proposed hydropower scheme; Hydrology Report.

I have also reviewed additional information received in response to section 92 RMA requests, along with the following:

3.0 Draft Conditions 17 June 2008
5.0 Engineering
  5.1 MHP Failure Modes and Consequences Report July 2008 – Issue 5
  5.2 Dam performance
  5.4 Preliminary Stability Assessment 17 June 2008

I have also taken into account issues raised by submitters in relation to the effects on the safety of downstream communities. These issues are usually associated with the broad headings of dam safety and adequacy of the design, dams and earthquakes, fault lines and geological instability at the dam site and surrounding the reservoir.

In addition I carried out a site visit on the Wednesday 5th March 2008.

On 13 March 2008 Dr Bruce Riddolls and I met in Wellington with Mr Nigel Connell and Mr John Black at the Damwatch office along with Mr Royden Thomson (geology consultant) to discuss technical areas associated with the dam and natural hazard risks within the reservoir.

Personnel from Riley Consultants have also provided input into the process of review of the AEE and supporting documents.

This review has only considered the information that has been made available to date. It is possible that my conclusions may be altered in response to further investigation and/or new information that becomes available prior to or during the hearing of the applications.

2.0 Submissions

The following issues were raised by submitters in relation to the effects due to dam engineering activities in particular:

- Earthquake risk and potential threat to life
- Lack of completed engineering work
- Safety issues associated with geological instability
- Lack of assessment of dam safety

- Lack of diagrams, description or discussion on the extent of downstream damage in the event of full or partial dam failure
- Proximity of the dam to the Glasgow fault and the lack of information on the fault
- Dam safety in areas of such high seismicity
- Geotechnical conditions within the dam foundation
- Landslides within the gorge and overtopping waves
- Catastrophic effects of dam failure
- Landslide generated waves overtopping the dam, flooding residents below with little warning

3.0 Assessment of Effects

I have reviewed the assessment of effects (potential effect of low probability and high potential impact) related to dam safety, and have taken into account the mitigation proposed by the applicant via the proposed draft consent conditions. This information is discussed below, with a focus on the key issues:

- The conceptual nature of the design at this stage of applying for resource consents
- The potential consequences of dam failure and the potential impact classification
- The information available on extreme loads
- The information available related to the dam foundations
- NZSOLD Minimum Procedures and Dam Stability Criteria
- Other relevant international dam stability criteria
- Building Act requirements
- Other issues related to risk mitigation.

3.1 Introduction

The applicant proposes to develop an 85 m high concrete gravity dam constructed from Roller Compacted Concrete (RCC). Design concepts have been provided but the AEE Report notes on p41 that "The Damwatch Report provides sufficient detail for the consent authorities to make a decision with respect to the proposal. Following granting of consents more detailed designs will follow."

The design at this stage is a feasibility level engineering design. I concur with Damwatch that the dam will be classified as High potential impact as defined by both the NZSOLD Dam Safety Guidelines and regulations associated with the Building Act 2004.

Damwatch notes that "important design parameters at Mokihinui will be the Probable Maximum Flood (PMF) and the Controlling Maximum Earthquake (CME) capable of inducing the largest seismic loading on the dam (an earthquake with a return period of more than 1 in 10,000 years). These are the most extreme loads used in dam design."

At this stage, the PMF and CME are not fully defined and further studies are warranted for the final design stage. The NIWA hydrology report indicates a likely range for the PMF, and there is also an indicative range provided for the ground accelerations associated with the CME.

However, knowledge is lacking on the potential activity and recurrence interval range that should be assigned to the Glasgow Fault located downstream of the dam site. The Glasgow Fault may well define what the CME is, to be used in final design.

Damwatch summarises the practices that will be followed to ensure the facility is designed, built and operated safely (i.e. to mitigate effects of high potential impact and low probability). These practices are:

1. The Mokihinui Hydro Proposal will be designed, constructed and operated in accordance with industry best practice

2. The standards of design that will be adopted for the final design, implementation and long term operation of the Mokihinui Hydro proposal will be as required in the NZSOLD Dam Safety Guidelines for a HIGH PIC dam

3. The design, construction and operation practices for the Mokihinui Hydro Proposal must address hazards, which in addition to natural hazards (such as storms and earthquakes) include construction issues such as material quality, or operational hazards that have the potential to impact the safety of the dam.

4. The NZSOLD Dam Safety Guidelines will be the minimum standards that will be adopted by Meridian Energy for design, implementation and long term operation of the Mokihinui Hydro Proposal.

Other organisations that produce relevant guidelines that are "recognised in New Zealand dam engineering as producing authoritative standards and guidelines that represent current international best practice" (Damwatch 2007) include:

- International Commission on large dams (ICOLD)
- US Federal Energy Regulatory Commission (FERC) – in particular Chapter 3 gravity dams (2002)
- US Army Corps of Engineers (USACE) in particular engineering manuals associated with gravity dam design, RCC dams and seismic analysis of concrete hydraulic structures
- Appropriate ANCOLD Guidelines
- Canadian Dam Association (CDA) Dam Safety Guidelines - recently revised in 2007.

In the draft Schedule A Consent Conditions, Meridian Energy proposes the NZSOLD Dam Safety Guidelines as the basis for design, construction and maintenance of the dam.

In the following sections I discuss various aspects related to dam breach and safety, dam stability criteria, the Building Act requirements, and other issues related to risk mitigation for the purpose of determining whether this leads me to conclude that the scheme design standard conditions are sufficient or not, or whether modified or additional conditions are, in my opinion, necessary.

3.2 Breach Consequences and Potential Impact Classification

It is common practice in dam engineering to assess the consequences of a hypothetical breach of a dam, and to rank dams in categories related to life safety and third party economic damages and environmental losses. Such philosophy is included in the NZSOLD Dam Safety Guidelines and regulations under the Building Act (2004) dam safety provisions.

In the Executive Summary of Damwatch(2007) it is stated "there would likely be several people at risk if the dam were ever to breach" and on page 26 "the Population at Risk (PAR) in the valley downstream of the dam (including Seddonville) would likely exceed the threshold of 11 on Table 3.3." Flood inundation maps for sunny day breaches provided in response to a S92 request (*Potential Failure Modes and Consequences of Failure for Input to Dam Design)* indicate that there are many buildings at Seddonville, in the vicinity of Mokihinui River Bridge and Summerlea that are at risk of inundation. Any temporary residents at the Mokihinui camp ground would also potentially be exposed. I have not undertaken any further assessment of the population at risk, however it may well be that the PAR is more than 100 when both permanent and temporary populations are considered. The applicant in response to a S92 request indicates a preliminary assessment of the PAR as 92 persons, which appears to exclude temporary populations such as whitebaiters or camping ground residents. The population at risk will certainly exceed the threshold of 11. In my opinion the dam breach scenarios considered to determine the inundation area and population at risk are reasonable.

I concur with Damwatch that this is a High PIC dam, and that the requirements based on PIC rating outlined in NZSOLD Table III-2 related to dam design, quality assurance, Investigations, design standards and methods, construction, commissioning will need to be followed, along with the dam safety requirements related to dam safety assurance programmes and annual dam compliance certificates required under the Building Act 2004.

I also concur that the PIC rating of High is only a consequence rating and does not imply any sense of likelihood of dam breach.

Damwatch has presented information that suggests an annual likelihood of dam failure at 10^{-7} (1 in 10 million chance per year). The International Commission on Large Dams in 1983 published statistics on the causes of dam failures.

For embankment dams, flood overtopping caused 48% of failures, and internal erosion through the embankment of foundation resulted in a further 40% of failures. Slope instability was related to 8% of failures, and other mechanisms accounted for the remaining 4%.

For concrete dams, flood overtopping accounted for 40% of failures, foundation strength 15%, foundation erosion and seepage 30%, and other causes were 15%. Earthquake failures, predominantly associated with earthdams account for about 1% of all failures.

Where this data has been used to estimate the annual probability of dam failure, the database indicates about 1 in 6000 for embankment dams and 1 in 10,000 for concrete dams.

However, this data is misleading when it is applied to an individual dam as it averages the good with the poor. Also a disproportionate number of dams failed with first filling, and new well-designed dams and existing dams with more than 5 years of service life have lower annual probabilities of failure.

Since these statistics were published, dam engineering has progressed further in developing and revising design standards for dams based on the consequences of failure, failure mode analysis has become more prevalent and rigorous, and dam safety assurance programmes are now commonly implemented to manage residual risks during the life of a dam.

In my opinion, it may be optimistic to consider the likelihood of the Mokihinui dam failing being 3 orders of magnitude lower than the historical rate of failures. On the basis of data available to me, I am not prepared to venture a figure as to the likelihood of failure other than to state that in my opinion it would be extremely low if the mitigation measures and design standards indicated in the Damwatch project engineering report are followed, along with review processes.

3.3 Extreme Loads

3.3.1 Flood Loads

Damwatch indicates the PMF flood used to size the spillway has a peak flow of 7200 m^3/s, but that a full study based on rainfall runoff modelling is required during final design. Meridian's S92 response 5-3 indicates the highest preliminary estimate for the PMF is 12,900 m^3/s and that an option is to raise the parapet walls of the dam by an additional 4 metres to contain the flood. If the final PMF flow is higher than the preliminary estimate, and a higher lake level results, then the dam section may need to have a slight adjustment of upstream and downstream slopes to ensure stability criteria are met for the revised lake level. In my opinion any subsequent change in effects relating to engineering aspects would be minor and mainly related to the scale of activities, such as concrete volumes. The effects of an additional 4 m rise in lake level may not be minor. However, I do not have information that allows me to quantify the additional effects. The likelihood that any additional effects beyond those described by the applicant due to additional reservoir rise are extremely low, and relate to the probability of an event that causes flows to exceed 7200 m^3/s.

3.3.2 Earthquake Loads

Damwatch indicates that if the Glasgow fault is active the dam would need to be designed for peak ground accelerations approaching 0.9g. The maximum design earthquake (MDE) shaking loads at the site will be finalised in the detailed design stage, following a more in-depth assessment of the local geology and faulting. In the S92 response, Potential Failure Modes and Consequences of Failure, (Issue 5) there is a comment on p3 “Structural analysis of the dam concept proposed for Mokihinui indicates that a concrete dam can be designed for this site to withstand shaking that would occur from a major earthquake (with ground accelerations up to 0.9g) and safely retain its reservoirs.” My reading of the preliminary stability assessment report is that the concept design has not reached the point where the above statement is demonstrably correct. Some sections of the dam that were analysed did not meet NZSOLD post-earthquake stability requirements and the analysis is only preliminary. It is based on assessed foundation strength parameters, unverified by testing for this dam site. Further comment is provided in Section 3.5 of this report.

A further s92 response 5-2 covers Observed Performance of Concrete Dams during Earthquakes. I acknowledge the good performance of concrete gravity dams under earthquake loads, and that although some dams have cracked (Koyna, Sefid Rud) none have failed to retain their reservoirs. With repair, the cracked dams have returned to service.

I have no information on the high RCC dams that have been reportedly designed for ground acceleration greater than 0.5g, and cannot indicate whether any have been designed for accelerations as high as 0.9g. I have not seen any detailed reports on the Shapai RCC arch dam that was near the epicentre of the recent Wenchuan earthquake in the Sichuan Province of China, but I am aware there were no reported safety concerns.

I am aware from published technical papers that Aviemore dam, which has concrete gravity dam intake and spillway blocks founded on greywacke on the Waitaki River was re-evaluated for high earthquake accelerations. I am not aware of the analysis undertaken nor the basis for others concluding the dam generally meets modern dam safety criteria.

The design accelerations for the proposed Mokihinui dam are at the edge of the envelope with respect to designs in high seismic areas. I expect that the analysis to determine the potential damage and post earthquake stability will need to progress from the more routine linear elastic 2-D analysis of selected dam blocks to state of the art non-linear analysis, possibly 3-D analysis of the dam and its foundations. I am not aware of the more sophisticated and complex type of analysis being done in New Zealand, and it may require a specialist consultant overseas with competency in this field to undertake the work.

I also caution against our reliance on peak ground acceleration as the basis of design. An increase for example in acceleration from 0.5 g to 0.9 does not necessarily mean an increase in earthquake load by a factor of 1.8. What is important is the frequency content of the earthquake motions. A very high peak ground acceleration in close proximity to a fault may be associated with a high frequency spike that is not close to the main vibration period of the dam, foundation and reservoir structure. This can result in limited response of the dam to such a spike. What is important is the design mindset that acknowledges the high seismicity of the area. This mindset will allow the design to progress from the start with detailing that will be aimed at reducing high earthquake stresses in the dam and hence the damage potential.

In my opinion a consent condition is required to ensure the adequacy of selecting appropriate earthquake motions for the seismic design of the dam, and peer review of this aspect. I do not consider the draft conditions proposed by the applicant adequately address this aspect. I will discuss the Building Act later in this report, but I do not think obtaining a Building Consent for the dam necessarily guarantees the seismic design being to international best practice.

3.4 Dam Foundations

At this feasibility stage of the design, the geology of the dam site and surrounds is as described in the Damwatch Project Engineering Description Report. It is based on surface mapping and selected drillhole investigations into both granite and greywacke, which form the foundation rock types. In my opinion the investigations are appropriate for the feasibility stage of the project, but more investigations and testing will be required to provide well defined strength parameters for the rock mass and defects. In the S92 response 5-4, preliminary estimates of rock mass shear strengths are used to provide an assessment of the dam's stability against sliding failure within the concrete and at the base of the dam.

In my opinion, it is important to have a rock mechanics expert develop a geotechnical model of the dam site that adequately describes the shear strength of key features of the foundations that control its stability. Sliding on defects within the foundation may be a determining factor with respect to the stability of the dam. There is a danger that initial rock strength assessments developed from programs such as Roclab, and presented in the preliminary stability assessment become entrenched throughout the design process. Wherever possible, foundation strength data for high PIC dam structures should be based on comprehensive laboratory and/or site testing. The designers will need to also consider the difference in the rock mass modulus between the greywacke and granite in the detailed design of the dam, to prevent cracking of the dam body.

Draft consent condition 13 includes a point to "adequately investigate the foundations." This compares with NZSOLD Guideline recommendations that "geotechnical appraisals should be all embracing including, engineering geological evaluation and comprehensive site investigations". Draft consent condition 14 does not in my opinion give enough assurance that the investigations will adequately establish the engineering properties of the foundation. I am recommending the design process has an element of peer review in selecting critical stability and strength parameters.

3.5 Dam Stability Criteria

The S92 response report Preliminary Stability Analysis for Conceptual Design presents an analysis of some typical sections through the dam and compares the stability to acceptance criteria sourced from Table B.6.2 of the NZSOLD Dam Safety Guidelines. This table and the accompanying footnotes was sourced from the 1999 edition of the Canadian Dam Association Dam Safety Guidelines. In Attachment A I provide copies of selected pages from:

1. Acceptance criteria from NZSOLD (2000)
2. Acceptance criteria from CDA (1999)
3. Acceptance Criteria from CDA (2007)
4. Acceptance Criteria from FERC (2002)
5. Acceptance criteria from USACE (1995)
6. Revised criteria from USACE (2005)

I wish to comment on recent trends in concrete gravity dam stability criteria, but before doing so I note that the preliminary stability analysis indicates that some dam sections would not meet the NZSOLD post-earthquake criteria based on the material properties assumed in the analysis.

The preliminary analysis is based on typical dam sections for the purpose of developing the dam concept. Some modification of the dam cross-section to meet all stability criteria may or may not occur during final design once all analyses are complete.

I note in the preliminary stability analysis of the dam presented by Damwatch, that both the usual load and post-earthquake load conditions are based on a lake level at the crest of the spillway. In my opinion, this is not conservative enough for this catchment where floods are large relative to the bypass facilities, and where the lake will rise above the spillway crest under moderate floods. The Canadian Guidelines for example consider usual loads to extend out to events with a 50 year return period and unusual loads to extend out to a return period of 1000 years. . The design criteria needs to define some element of flood loading for the usual, unusual and post-earthquake analysis, with peer review as to its appropriateness.

In the final design of the dam, more sophisticated and detailed earthquake analyses will be required and some refinements may be required to the design of the dam such as keying the dam into the right abutment and providing local thickening at the base of the dam. Curving the dam axis may also be an option.

If some of these refinements are adopted in the final design then the effects relate to slight increases in the volume of excavation and concrete work.

I now comment on trends in dam safety criteria. FERC (2002) introduced an alternate sliding stability criteria where the sliding factor of safety is determined from only the friction component of strength and any cohesive bond is ignored at the dam foundation interface. CDA(2007) has also followed this practice and recommended a sliding factor of safety based on friction only. It recommends that the use of a cohesive bond in calculating the sliding factor of safety should be done with extreme caution. CDA (2007) also indicates that usual loads can extend out to events with a return period of 50 years. USACE (2005) uses a return period of 10 years for usual loads. Wherever the boundary is defined between usual, unusual and extreme loads, it is my opinion that the stability criteria against sliding failure, position of resultant load and dam stresses should be applied using reservoir and tailwater combinations that apply at the maximum usual and unusual loads. Whatever dam stability criteria are finally proposed by the lead designer as meeting best practice should be confirmed by peer review.

FERC (2002) is more conservative than CDA (2007) with respect to minimum factors of safety for sliding with the no cohesion (friction only) approach. As an example, a factor of safety of 1.5 or greater is required for the worst static case by FERC where this only applies for usual loads with CDA (2007). For post earthquake conditions, FERC (2002) requires a minimum factor of safety of 1.3 whereas CDA (2007) requires greater than 1.1. Similarly FERC requires a minimum factor of safety (friction only) of 1.3 for the PMF and CDA (2007) requires 1.1. Some of these criteria are more conservative than given in the NZSOLD Dam Safety Guidelines.

Both FERC (2002) and CDA (2007) no longer specify a sliding factor of safety to be applied for earthquake loading. The analysis of the dam under earthquake loading is performed to establish the post-earthquake condition of the dam. Again there are differences between various guidelines as to what the post-earthquake stability criteria should be.

As part of this review I considered developing and proposing a set of acceptance criteria conditions for dam stability that is more conservative than given in NZSOLD Guidelines, based on some of the trends and factors described above. However, on reflection, that would lock in criteria that may still be inappropriate and not supported by the lead design team or peer review process. I consider a better alternative is to have the lead designer consider the information presented above and the points I have raised. The lead designer would then be responsible for developing the design criteria for the dam, and subjecting this to confirmation by peer review. Conditions can be developed that reflect this philosophy as indicated in the overall planning report.

3.6 Other Criteria (Low level Outlets)

Section 9.7 of the Damwatch Project Engineering Description discusses low level outlets and advises of the intent to plug the diversion culverts on completion of lake filling. The report notes the NZSOLD Dam Safety Guidelines do not specifically require the provision of low level outlets.

Section B.7.5 in the NZSOLD Dam Safety Guidelines on Reservoir Drawdown Arrangements comments that "depending on the dam type and hazard potential, it may be prudent to incorporate measures to draw the reservoir down a certain amount after a severe earthquake."

Bypass valves are proposed for the powerhouse, but their capacity is subject to final design. Based on the information provided, they would not have capacity to hold the reservoir down near the intake levels under flood conditions.

In commenting on the benefit of having the ability to lower the reservoir should the dam need repair, Damwatch comments the need for repair is "avoidable in good design, construction and operation. Many dams in the world do not have permanent large low level outlets." Although concrete dams have not failed under earthquake loads, some have been damaged sufficiently to require subsequent repair. In New Zealand, most major dams in the vicinity of potentially active faulting do have low level outlets.

At this stage there is no detailed dynamic analysis of the dam presented that allows me to assess the post-earthquake conditions for the dam. Some earthquake damage appears possible and if the post-earthquake stability is near the minimum requirement, then footnote 5 associated with CDA (2007) indicate that this condition should not be allowed to remain for any length of time. Remedial action should be carried out as soon as possible such that the factors of safety are increased to the level of the pre-earthquake conditions. There is no information provided that indicates to me whether the dam would or would not need repair subsequent to a severe earthquake.

If the dam does require repair, then it might take a few years to investigate and complete. This then raises in my mind the issue as to how much lake level control can be achieved with or without a low level sluice. No information is provided by the applicant with respect to this aspect. The cost of increasing the volume of the dam to handle some flood loading and still meet stability criteria in the post-earthquake situation may be comparable to the cost of a gated outlet with energy dissipation downstream of the dam.

In my opinion the arguments for and against a low level outlet(s) need to be challenged as part of the design and review process. I have not sought a condition with respect to providing a low level outlet as there is insufficient information available to indicate whether providing an outlet would markedly change the reservoir levels that the dam may be exposed to post-earthquake. It may be better to design the dam and confirm post-earthquake stability with an appropriate flood surcharge on the dam. This design process may result in a dam section that then becomes more earthquake resistant. I therefore consider it better to leave the decision on the low level sluice to the final design and review process.

3.7 Building Act (2004)

A building consent will be required for the dam from the Regional Council. I understand the West Coast Regional Council has transferred its powers as a building consent authority for dams to the Otago Regional Council.

In applying for a building consent the applicant will generally need to supply the following documents related to the dam design;

I. Foundation investigation data
II. Design report
III. Peer review report(s)
IV. Drawings and Plans
V. Specification for the works

A building consent authority must grant a building consent if it is satisfied on reasonable grounds that the provisions of the building code would be met if the building work were properly completed in accordance with the plans and specification that accompanied the application (S49).

For dams, the key element of the building code is clause B1 Structure aimed at preventing structural failure of buildings throughout their lives. Standards for dams are not codified, so it is appropriate, in my opinion, to look to the NZSOLD Dam Safety Guidelines and other international guides of best practice to establish the design criteria that will achieve the objectives of the Building Code.

It is also, in my opinion, appropriate to set conditions that relate to design criteria, design processes and independent review processes under the RMA to mitigate the potential effects (low probability which has a high potential impact) to ensure adequate risk mitigation. This is particularly so as the Building Code is not specific in relation to dams regarding the verification method by which compliance with the building code may be verified.

After the dam is commissioned, the dam safety provisions of the Building Act apply. These require a dam safety assurance programme, including an emergency action plan to be prepared for the dam and certified by a “recognised engineer”. An annual dam compliance certificate is also required to confirm that the procedures of the dam safety assurance programme are being complied with.

3.8 Peer Review

Draft consent condition 15 touches on the issue of peer review.

As noted above, a building consent will be required prior to any construction. In my opinion the consent holder will need to assemble peer reviewer(s) that cover the main aspects of a gravity dam design and key issues of foundation stability, earthquake design and post-earthquake stability. Peer review reports would be expected to be provided by the consent holder in applying for the Building Consent.

The Regional Council (or its contracted agency) is likely to employ specialist technical advice in processing the dam consent application, but the role of this reviewer is to act for the Regional Council in a regulatory review role, not as a technical reviewer of the proposed scheme design.

A recognised engineer under the Building Act has competencies to assess potential impact classifications and develop and certify dam safety assurance programmes. Being a recognised engineer does not guarantee sufficient design competencies to review the proposed Mokihinui scheme design and advise as to whether accepted industry standards are met.

In my opinion, a peer review consent condition is required and it must reflect the requirements of the consent holder to ensure adequate independent peer review through both the design and construction phases of the project, in accordance with NZSOLD Dam Safety Guideline recommendations for High PIC dams. Independent peer review is likely to comprise a panel with the experience and competence to cover all aspects of the design and construction that relate to dam safety. The overall planning report proposes such conditions.

4.0 Conclusion

The main conclusions from my evidence are;

1. I concur with the High potential impact consequence rating for the dam, but consider the population at risk will be higher than initially implied or stated by the applicant.
2. The design of the dam is at a feasibility stage, and further studies are required to define the extreme flood and earthquake loads for the final design of the dam.
3. I concur with the Damwatch position that the NZSOLD Dam Safety Guidelines should define the minimum standards for the design of the dam.
4. In my opinion other internationally accepted gravity dam design criteria indicate a trend to more conservative acceptance criteria for gravity dams than given in the NZSOLD Guideline.
5. An element of flood loading should be applied to the maximum usual and unusual load conditions.
6. The lead designer should develop design criteria that reflect current international best practice and subject the criteria to independent peer review.
7. An element of flood loading should also be considered for assessment of post-earthquake stability. This should relate to the level of flood control available with or without a low level dewatering sluice.
8. The arguments for and against a low level sluice need to be challenged through the design and peer review processes.
9. The Building Code does not in my opinion provide sufficient dam safety guarantees and hence I recommend consent conditions related to the design and independent review processes.
10. An independent peer review process is required through the design, construction and commissioning phases of the project.

5.0 References

Canadian Dam Association (1997) Dam Safety Guidelines

Canadian Dam Association (2007) Dam Safety Guidelines and Associated Technical Bulletins

Federal Energy Regulatory Commission (2002) Chapter 3 Gravity Dams

NZSOLD (2000) New Zealand Dam Safety Guidelines

USACE (1995) EM110-2200 Gravity Dam Design

USACE (2005) EM110-2-2100 Stability Analysis of Concrete Structures.

Attachment A– Acceptance Criteria for Gravity Dams