Interim Report of the Joint Experts' Meeting
May 21, 2013
in Tokyo

1. Background and Objectives

At the request of Japan Atomic Power Company (JAPC), both the Third Party Review Meeting (TRM) and the Independent International Expert Review Group (IRG) have been engaged in an independent review of the JAPC report and response to the Nuclear Regulatory Authority's (NRA) report on the faults and shatter zones at the Tsuruga NPP.

The objective of the work of each group has been to provide an independent geological and engineering appraisal of the interpretations on faults/shatter zones, using their extensive experience from visiting geological and post-earthquake sites worldwide, and to make recommendations on the way forward for resolving differences and uncertainties in a risk informed way.

Based on the discussions and site-investigations carried out so far by both groups, this joint interim report by the experts was developed in discussion during the joint meeting held in Tokyo on May 21, 2013.

2. Experts in attendance

TRM: Woody Epstein, Senior Principal Consultant, Scandpower,
Visiting Professor of École Polytechnique, Paris
Professor Koji Okumura, Hiroshima University
Dr. Hirokazu Kato, Emeritus researcher of the National Institute of Advanced Industrial Science and Technology

IRG: Professor Neil Chapman*, University of Sheffield & MCM Consulting
Dr. Kelvin Berryman, GNS Science

*: No attendance, but provided extensive input by e-mail

3. Past Meetings and Investigations

March 28, 2013	TRM meeting in Tokyo
March 29, 2013	Geological investigation at Tsuruga PS by TRM
April 10, 2013	Initial review by IRG
April 24, 2013	Joint expert meeting of TRM/IRG at Menlo Park, CA
May 20, 2013	Geological investigation at Tsuruga PS by TRM/IRG
May 21, 2013	Joint expert meeting of TRM/IRM in Tokyo

4. Summary

4.1 General approach and adequacy

a. The JAPC's report represents an appropriately comprehensive approach, the methods already used by the JAPC are appropriate, the data, in general, that have been presented support the JAPC's preliminary conclusions.
b. However, there is a need to look at a wider area to provide a context for the faults and shatter zones observed near the site. These data need to be supplemented by data from seismology, geodesy, and volcanic ash distribution from the wider area surrounding the plant.
c. The analysis of fault kinematics and microstructures seems reasonable, but further analysis is required.
d. The NRA has assumed connections between geological features in a way that the JAPC disagrees with. This disagreement can only be resolved by additional field observations and discussions between the JAPC and the NRA.
e. Both the JAPC and the NRA reports need to provide additional information (see [b] above), and this needs to be evaluated in a peer review to ensure that these issues are addressed comprehensively.
f. The JAPC's investigation is on-going and they will present the results to the NRA as they become available, probably by the end of June.

4.2 Interim appraisal of the geological issues

a. The continuity of the D-1 shatter zone
    - The G fault and the D-1 shatter zone are very similar in their macroscopic structural characteristics (fault gouge, strike and dip), and their displacement senses are also the same. Therefore we judge the G fault and the D-1 shatter zone are likely to be the same feature.
    - On the other hand, the K fault and the D-1 shatter zone have different macroscopic structural characteristics, and their displacement senses are opposite.
    - The continuity of the K fault needs further field study.
b. The activity of the D-1 shatter zone, the G fault and the K fault
    - Our judgment is that the D-1 shatter zone – the G fault has not displaced any of the alluvial layers above bedrock. Layer 5 several units higher and younger than the upper termination of the D-1 shatter zone and the G fault probably contains traces of the Mihama-tephra deposited 120,000 to 130,000 years ago.

Palynological data from layer 5 also supports an age for this layer of about 120,000 to 130,000 years.

- The K fault displaces younger layers than the D-1 shatter zone – the G fault but also does not displace unit 5 that contains probable traces of the Mihama tephra. .
- However, the identification of the Mihama tephra needs to be defined by additional information, and these data need to be independently verified by a Japanese tephra expert.

c. Effects of displacement of the Urasoko fault
   - We judge that field evidence shows that neither the D-1 shatter zone – the G fault nor the K fault have had any sympathetic rupture in the past 120,000 to 130,000 years when the Urasoko fault has been repeatedly active, most recently around 4,000 years ago and on average every 5,000 years prior to that.
   - Undertaking further mechanical and kinematic analyses of the conditions under which sympathetic rupture and deformation of the D-1 shatter zone – the G fault could occur as a result of movement on the Urasoko faulting is important, and are recommended.

4.3 Recommendations

a. An effective process of full and open-minded communication between the JAPC and the NRA is essential.
b. Joint on-site geological investigations and discussion are recommended to be held between the members of the JAPC, the NRA and independent experts.
c. Application of international best practices such as the IAEA’s risk approach and the experience of California’s Diablo Canyon NPP Long Term Seismic Program – LTSP are recommended so that the regulator can come to the most appropriate judgment.

5. Detailed discussions

5.1 General approach and adequacy

a. The JAPC’s report presents a comprehensive approach, although there is a need to investigate a wider geographical area around the plant in order to understand the geological context of the site.

   The methods already used by the JAPC are suitable, but they should be supplemented by data from seismology, geodesy, and volcanic ash distribution in the area.

   In general, the data presented support the JAPC’s conclusions. The JAPC uses fault orientation and fault kinematics strongly in their arguments. The analysis of fault kinematics and microstructure seems scientifically reasonable, but it is possible to over-interpret their significance. Therefore, a wider area must be included.

The NRA's report looks at the issue on a micro scale, without considering the potential interrelations between the various tectonic (or non-tectonic) features within the site area. The NRA has connected geological features in a way that the JAPC disagrees with, and this disagreement can only be resolved by additional field observations.

Both the JAPC's and the NRA's reports would need to provide additional information or interpretation on seismology, geodesy, regional geology, and volcanic ash distribution in the area to justify their position, and this needs to be evaluated by an independent expert peer review to ensure that the issues are addressed comprehensively. Only then can the public be assured that regulatory decisions are based on scientific evidence and are in compliance with the recommendations of the IAEA.

b. The deterministic criteria defining an "active fault" in the latest regulatory definition in Japan is based on the length of time since the last activity (currently 120,000 to 130,000 years) and does not match best international practice for assessing geological faults in the context of the safety of nuclear facilities. A thorough assessment of whether a specific individual fault is 'active' or not or poses a threat to safety requires a full understanding of its history, tectonic context, and impact on the risk and safety of the NPP.

c. With respect to fault kinematics, field evidence shows that neither the D-1 shatter zone – the G fault nor the K fault have had sympathetic rupture during past movements of the Urasoko fault for at least 120,000 to 130,000 years. Nevertheless, further mechanical and kinematic modeling should be undertaken to analyze the conditions under which sympathetic rupture and deformation of the D-1 shatter zone – the G fault, or other bedrock weak zones could occur as a result of movement on the Urasoko fault.

d. To assist in coming to a judgment regarding fault capability, collecting and evaluating a more comprehensive suite of data covering a larger area is recommended, from existing surveys and observations, and from further work.

e. If an unequivocal and agreed outcome from deterministic approach is not achievable for (a)-(d) above, then based on the most advanced international developments for existing NPPs, this same information can be used in a probabilistic fault displacement hazard analysis (PFDHA). This can be linked to the Tsuruga NPP's structure, systems, and component data, and the plant probabilistic risk-based safety assessment can be quantified to understand the fault impacts, if any, on risk and safety.

f. The JAPC and the NRA should consider negotiating a more considered basis, scope and timescale for tackling the fault status issue.

5.2 Geological issues

a. Continuity of the D-1 shatter zone

Correlation of the D-1 shatter zone in outcrops, on existing geological drawings from the design and construction of the Tsuruga NPP, and from drill holes, as displayed in the JAPC Report appears reasonable, but there is need for further verification.

(a) Macroscopically the D-1 shatter zone consists of a distinctive shear plane with white to pinkish-white fault gouge (1-10mm thick) with N20°E-N30°E strike and steep westward dip, within a ~1m wide cataclasite zone with fractures or joints of NS and N20°E-N30°E strike dipping steeply to west. The shear plane with fault gouge juxtaposes granitic rocks of different color and texture, indicating a significant amount of slip. Both or one side of the white fault gouge zone is bordered by black bands.

(b) These characteristics are important for correlating the D-1shatter zone with the G fault, or distinguish the D-1 shatter zone from the K fault. Before the examination of microscopic features, it is important to confirm such macroscopic fault zone structures in boring cores and existing maps and photos.

(c) The D-1 shatter zone can be modeled as a N-S striking right-stepping en-echelon suite of shear planes connected by N20°E-N30°E striking oblique shear planes within a network of joints with N-S and N20°E-N30°E strike, though this model needs improvement and further verification by structural geologists.

b. The G fault characteristics and continuity to the D-1 shatter zone

The G fault in the North pit of the D-1 trench and the D-1 shatter zone on the outcrop just south of the 2nd unit are identical for their macroscopic structural characteristics. This indicates the possibility that they had been formed at the same time in the location under a unique geological environment.

(a) In macroscopic observations, the G fault in the North pit accompanies a shatter zone consists of a distinctive shear plane with yellowish white fault gouge (1-5mm thick) of N20°E strike dipping steeply to west, ~1m thick cataclasite zone with fractures or joints of NS and N20°E-N30°E strike and steep westward dip. The shear plane with fault gouge juxtaposes granite rocks of different color and texture, indicating significant amount of slip. One side of the yellowish white fault gouge zone is bordered by a black band.

(b) The yellowish color of the fault gouge of the G fault is judged to be due to oxidation by ground water and weathering. The G fault outcrop is close to a probable Middle Pleistocene unconformity on which lies ~20m of gravel.

c. The K fault in the D-1 trench

The K fault appears to have less total displacement than the D-1 shatter zone – the G fault as evidenced by thin gouge and lack of development of a cataclasite zone. Further mapping of the extent and age of rupture of the K fault is required.

(a) There is a very thin (1-2mm) fault gouge along a clear shear plane, but there is no significant brecciation associated with the shear plane. Sparse joints and cataclasite around the K fault are old and incoherent structures.
(b) The fault trace curves significantly from NS to NW-SE southward. The NW-SE trend is different from the G fault and the D-1 shatter zone.
(c) The upper termination of the K fault is within layer 3 where the fault plane dip is less than lower in the outcrop and there is some upward splaying of planes that are common features for reverse faults in unconsolidated near-surface sediments.
(d) The difference in sedimentary layer thickness (in cm-order) across the K fault plane in the layer unit 3 may indicate small amount of strike-slip movement, as do striations on the fault plane. Further study of the slip vector is required.
(e) The amount of slip in the latest event could be as much as 50 to 80 cm as seen as the displacement of layers in the upper part of layer 3 near the upper termination of the fault. This measurement of the amount of single event displacement needs to be examined further and replicated where possible in additional outcrops.
(f) The tectonic background of the K fault needs to be examined further.

d. Regional tectonics and formation of individual structures

The D-1 shatter zone, the G fault and the K fault are structurally different from each other. Unless there is evidence for west-side-up reverse faulting on the D-1 shatter zone and the G fault, then the K fault is an independent structure. As well as microscopic observations, outcrop-scale and hand-specimen-scale observations need to be integrated to support this.

(a) The active tectonics in and around the Tsuruga peninsula are under an E-W to 120 degree compression stress field.
(b) The NS-striking and W-dipping D-1 shatter zone and the G fault may be reactivated only in a west-side-up reverse faulting in current tectonic conditions. Minor strike-slip component may accompany the dip-slip component, but dip-slip should be predominant considering the strike and the stress field.

(c) Microscopic structural analyses of the D-1 shatter zone and the G fault only show normal faulting with right-lateral strike-slip striations. Further thorough analyses should be carried out to exclude possibilities of over-printed reverse faulting.

(d) N-S striking normal faulting occurred in this area only in the Miocene (20 to 6 Ma: million years ago) when the Sea of Japan opened, under E-W extensional tectonic regime. The E-W compression stress field was initiated in the Pliocene (6 to 2.6 Ma) and has culminated after 1 Ma. Normal fault displacement on the D-1 shatter zone – the G fault is therefore inconsistent with the present-day stress field.

e. Stratigraphy and Chronology

Under current regulations the exclusion criteria for active fault definition, which is quiescence for 125,000 years, the K fault is not a problem, although it is necessary to collect more stratigraphic and chronological evidence to fix the age of the most recent activity.

The Mihama tephra seems to be a reliable time-marker, but the number of the grains is definitely small and its validity, as a constraining age marker needs further verification.

5.3 Mechanical and kinematical analyses

a. Mechanical and kinematical analyses of induced rupturing and deformation by a faulting event on the Urasoko fault are useful.

However, geological evidence of past rupture events and deformation models should constrain the analysis of sympathetic rupture of the D-1 shatter zone and the K fault with the Urasoko fault.

b. The JAPC has developed a numerical model of the likelihood of future simultaneous activity on the Urasoko fault and the shatter zones in the site. The numerical model includes elastic dislocation, uncertainty, developed as a Finite Element Model (FEM). The FEM, however, was developed using only a limited range of input parameter values. A full FEM study, with uncertainty as an additional parameter is suggested, to evaluate a family of displacement hazard curves and their recurrence frequency.

5.4 Probabilistic risk informed approach

If additional data gathering and analyses do not lead to resolution and agreement, a Probabilistic Fault Displacement Hazard Analysis (PFDHA) is recommended to be performed, which could lead to establishing a clear, risk-informed decision on Tsuruga’s future.

a. The risk informed approach to decision making is a key element in the US NRC licensing and decision making process.
b. Probabilistic risk assessment, including earthquakes, fragility, levels 1-3 assessments are considered " best practice" and essential for regulators from all over the world and the IAEA.
c. Probabilistic seismic hazard analysis (PSHA) is well known in the nuclear power industry and is used to analyze both ground motion and fragilities. It is accepted by the US NRC, the IAEA, the Swiss Federal Nuclear Safety Inspectorate, L'Autorite de Surete Nucleaire in France, and others.
d. PFDHA is not as well known as PSHA. PFDHA has been used most successfully at Yucca Mountain in the USA, and Krsko NPP in Slovenia, and its use was accepted by the US NRC. PFDHA has also been employed at high hazard hydro dams in New Zealand and elsewhere and in R&D studies in Japan examining procedures for waste repository site suitability.
e. At Yucca Mountain, a site-specific probabilistic analysis of fault displacement hazard analysis was done using two methods. These general methodologies are applicable to any region.

5.5 Earthquake engineering

Whether the D-1 shatter zone and the K fault are 'active' or not should not be the singular focus of safety for the Tsuruga NPP. All of the seismic issues – faults, earthquake criteria, adequacy of structures, systems and components, should be addressed in parallel to evaluate this safety issue. California's Diablo Canyon NPP case can be a good model for tackling the Tsuruga NPP case – both for the plant operator and the regulator.

5.6 Regulatory issues

Direct, clear, and complete scientific discussions and field investigations undertaken on an agreed basis by the JAPC and the NRA, as was undertaken in the Diablo Canyon NPP case, is strongly recommended.

Appendix 1: The Joint TRM/IRG Press Conference Statement

In March, 2013, the Japan Atomic Power Company retained two independent expert teams to each conduct an objective, third-party assessment regarding the shatter zone at the Tsuruga NPP.

One of the teams is the Third-party Review Meeting (TRM) organized by Scandpower, a member of the Lloyd's Register Group of Companies, headquartered in Norway.

The other team is the International Review Group (IRG), a group of experts in geology led by Professor Neal Chapman of the University of Sheffield, who is internationally well known in the field of geological disposal.

Since the end of March, 2013, each team has been independently carrying-out their assessments. Each team has delivered a report with recommendations.

One recommendation which the TRM made to the JAPC was that the JAPC must clearly explain to the media and the public the investigations and conclusions with regard to the fault issues at Tsuruga. This press conference is a first step towards this goal.

The subject of this press conference is to report the key points from the interim result reports by each team, and their recommendations. We hope that the reports will be published on-line by the JAPC in early June, 2013.

The Urasoko fault, which has been thoroughly studied over the years in its relation to the Tsuruga NPP, is not a part of our investigation

A key finding by both teams is that the JAPC has provided good geological evidence that the shatter zones and faults under investigation have not moved in the last 120,000 to 130,000 years. This means that under current nuclear safety regulations, fault activity is not an issue. In the spirit of good science, we suggest further investigations to confirm this interim finding.

Our other key findings are:

- There is no positive evidence that secondary fractures and old faults beneath the Tsuruga NPP can be classified as active according to current regulations;

- The JAPC is now gathering new data to confirm, or disconfirm, the JAPC positions, and time should be allowed to permit the outcome of these scientific investigations to be incorporated into any regulatory decisions to be made;

- Waiting for more studies to be undertaken poses no risk to the public because the Tsuruga NPP is in safe shut down;

- Both the JAPC and the NRA need to provide much more substantiated information before the investigations can be regarded as properly transparent and in compliance with IAEA recommendations and practices of other regulatory agencies worldwide;

- The results of the investigations should be used to understand the impact of the site geology on the plant safety goals which the NRA is now proposing, especially core damage frequency (CDF) and large early radioactive release frequency (LERF);

- The Long Term Seismic Program (called the LTSP) is an agreement between the Diablo Canyon NPP and the US NRC. Under the LTSP, Diablo Canyon constantly identifies, examines, and evaluates all relevant geologic and seismic data, and interpretations from around the world, and then reevaluates the seismic risk at the Diablo Canyon NPP data, both deterministically and probabilistically. We suggest that a program at the Tsuruga NPP modeled after the LTSP at the Diablo Canyon NPP will create open technical and policy communications with the NRA and the public.

Appendix 2: Probabilistic Risk-Informed Approach

Probabilistic risk assessments (including equipment breaking, earthquakes, flooding, loss of external power …) are considered “best practice” and essential by regulators from all over the world and the IAEA.

The NRC decided to implement "risk-informed approaches in 1993. As a result, when the NRC proposes a new regulation, the alternatives considered must include a risk-based alternative.

The "PRA Policy Statement" (60 FR 42622, August 16, 1995) formalized the Commission's commitment to risk-informed regulation through the expanded use of PRA. The PRA Policy Statement states, in part,

> “The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a manner that complements the NRC’s deterministic approach and supports the NRC’s traditional defense-in-depth philosophy.”

When doing an external event PRA for earthquakes, it is common practice to use probabilistic seismic hazard analysis (PSHA). PSHA is a method for calculating the range of ground motions which may impact an NPP and is well known in the nuclear power industry to analyze both ground motion and fragilities. It is accepted by the US NRC, the IAEA, the Swiss Federal Nuclear Safety Inspectorate, and L’Autorite de surete nucleaire in France. Also, in Mexico, the Commission Federal Electrdad (CFE) required PSHA for the Laguna Verde Nuclear Power Plant (LVNPP). PSHA was first implemented in 1985 and has continued with significant success to the present.

If additional data gathering and discussions with the NRA do not lead to resolution and agreement over the fault issues, then performing a probabilistic fault displacement hazard analysis (PFDHA) is recommended. This could lead to establishing a clear, risk-informed decision on the fault issues at the Tsuruga NPP.

PFDHA is not as well known as PSHA, however, it has been used successfully at Yucca Mountain, the Krsko NPP in Slovenia, at high hazard hydro dams in New Zealand, and in

R&D studies in Japan for examining procedures for waste repository site suitability. Its use is accepted by the US NRC.

Both the JAPC and the NRA must move away from the black-and-white situation of 'Yes the fault is active' versus 'No it is not active'. To arrive at the best decision between “active” and “not active” are the following intermediate steps:

(1) looking at the likelihood of fault activation (PFDHA);
(2) the probability of displacements of different magnitudes over different time periods;
(3) probabilistic ground motion studies (PSHA);
(4) probabilistic fragility analyses to understand the strength of the structures, systems, and components;
(5) and integration into the plant specific probabilistic and deterministic risk assessments.

Appendix 3: Earthquake Engineering

Whether the D-1 shatter zone and the K fault are 'active' or not should not be the singular focus of safety at the Tsuruga NPP. All of the seismic issues, faults, earthquake criteria, adequacy of structures, systems and components, should be addressed in parallel to evaluate this safety issue.

A general roadmap for this approach is shown below:

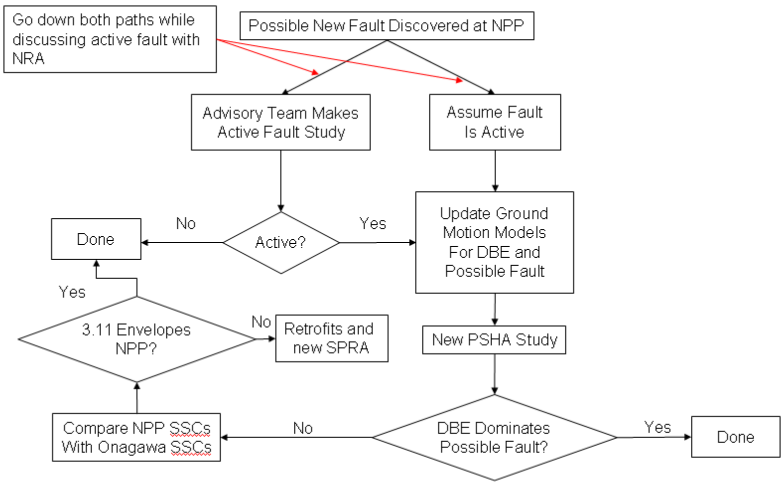

Figure 1: Please note that DBE means design basis earthquake, SPRA means seismic probabilistic risk assessment, PSHA means probabilistic seismic hazard analysis, and SSC means structures, systems, and components

This general roadmap indicates the studies required to assess the increased risk from the fault and shatter zones at the Tsuruga NPP. There are two basic success paths: (1) Show that a new fault is not active or (2) Assume that the fault is active and show that it does not dominate the site seismic hazard. Note that the PRA approaches PSHA and SPRA have important roles in assessing the additional risk.

Appendix 4: The Diablo Canyon Long Term Seismic Program

Direct, clear, and complete scientific discussions and field investigations undertaken on an agreed basis by the JAPC and the NRA, modeled on the Diablo Canyon Power Plant Long Term Seismic Program (LTSP), is the most important step forward for nuclear safety at Tsuruga and in all of Japan.

In July 14, 1978, the NRC Advisory Committee on Reactor Safety (ACRS) recommended that a seismic hazard and risk update of the Diablo Canyon NPP should be done within 10 years because of new science and new data.

In April, 1984, the ACRS recommended a LTSP-Seismic Safety Reevaluation, which the NRC approved the ACRS recommendation with a focus on four elements:

1. Continuing geology, seismology, and geophysics studies;
2. Continuing earthquake magnitude and source characterizations;
3. Continuing ground motion studies;
4. Continuing seismic margin evaluations and both probabilistic and deterministic risk analyses.

It should be noted that the Diablo Canyon NPP continued to operate during the study.

The LTSP was a great success. The NRC stated in June 1991 – Appendix C, U.S. Geological Survey Review:

> “The LTSP was planned and implemented to address a set of pre-defined, geologic issues, and considerable flexibility was demonstrated in responding to some new and unexpected findings such as the Los Osos and San Luis Bay faults. The broad range of methods used, the aerial extent of the study, and the depth to which critical issues were probed mark this as an unusually comprehensive site study of earthquake hazards. The credit for this effort belongs to the able and highly professional team assembled by PG&E.”

The Diablo Canyon NPP (DCNPP) case history is most relevant to the Tsuruga NPP shutdown and regulatory restart process. From 1973, at the surprise discovery of the active Hosgri fault, near DCNPP to 1991, the full-power license was threatened by active fault and related seismic safety challenges.

The end result was PG&E had adequately addressed all licensing issues under the LTSP and the USNRC authorized the permanent Full-Power Licenses.

The most important lesson for the JAPC and the NRA is the lesson of dialog between the utilities, the regulator, and the public. The example of DCNPP and the US NRC should be followed. DCNPP and NRC, and related advisors, agreed on a process to openly discuss the active fault challenges and develop a program to resolve all challenges; the program was open, transparent, with full disclosure about past mistakes and a commitment by DCNPP to work with the NRC.

A sensible solution in the national interest can only be achieved by maintaining and substantially improving the dialogue between the JAPC and the NRA.