Figure 4.28 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

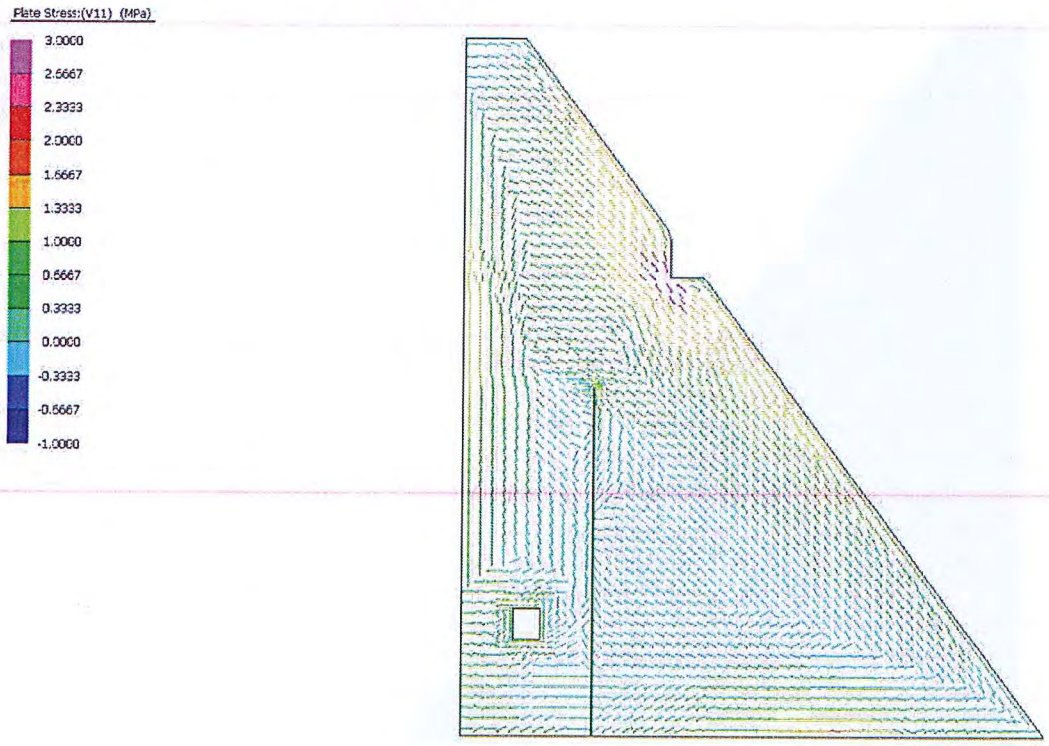


Figure 4.29 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Vertical Stress

Figure 4.30 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

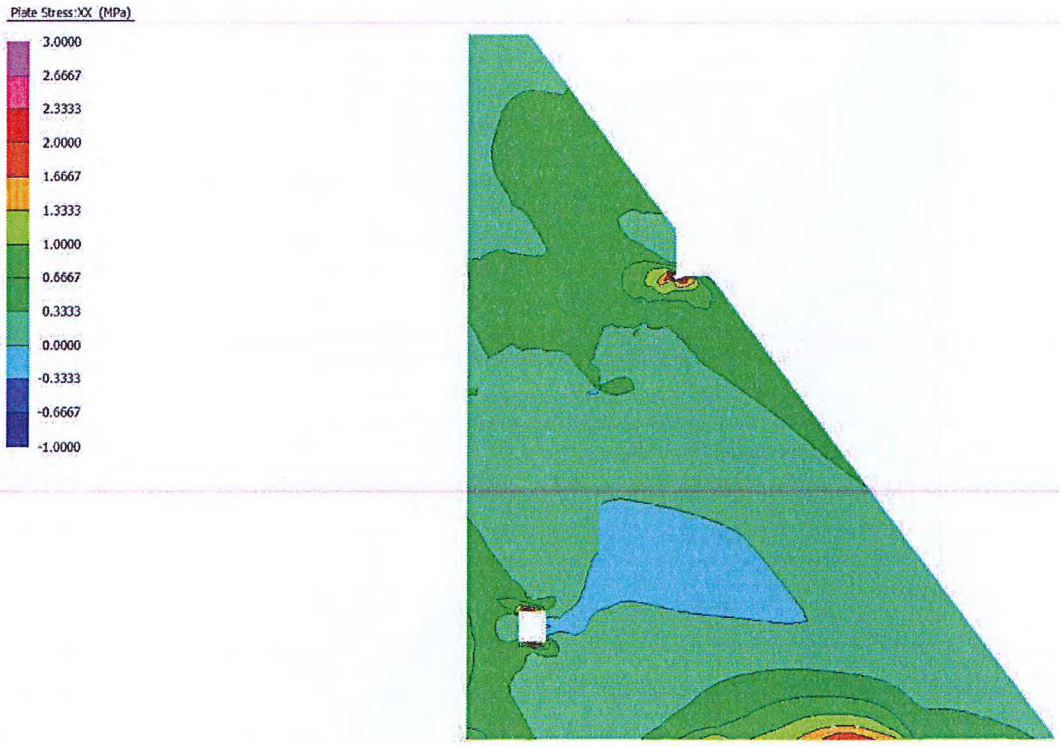


Figure 4.31 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

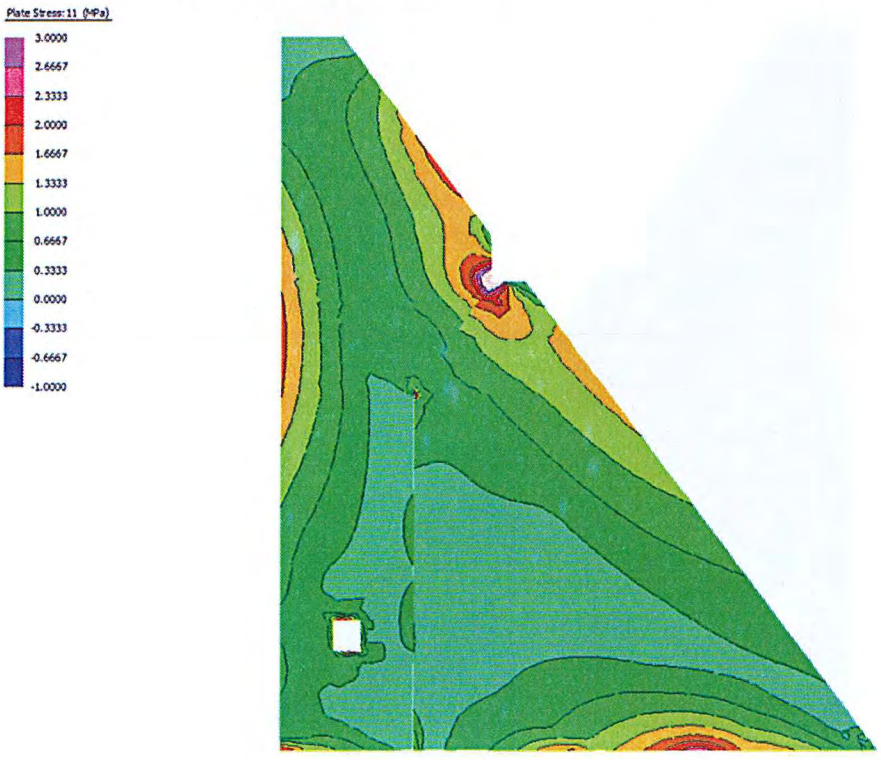


Figure 4.32 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

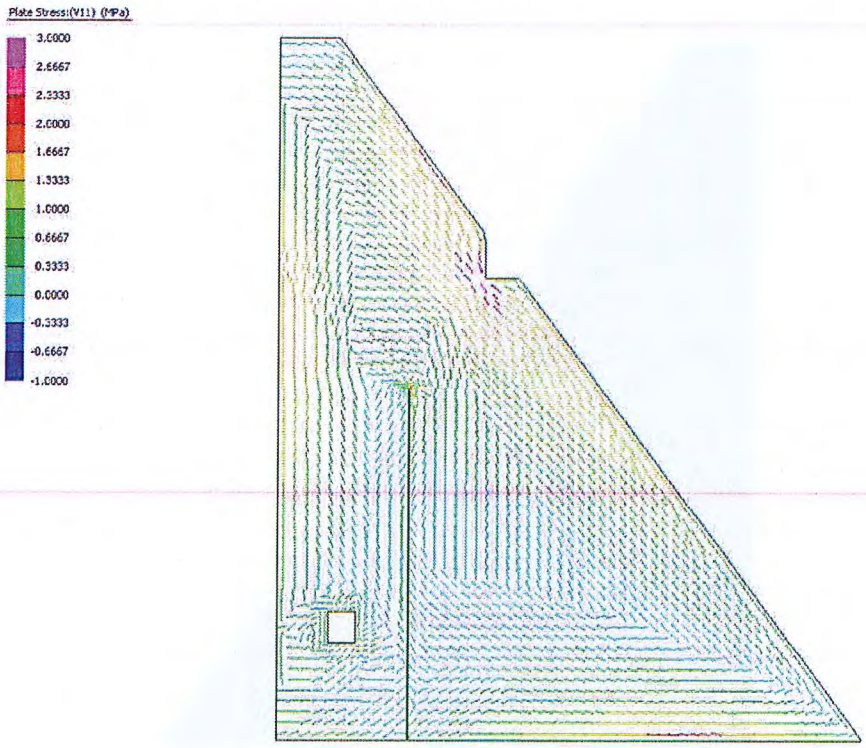


Figure 4.33 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Vertical Stress

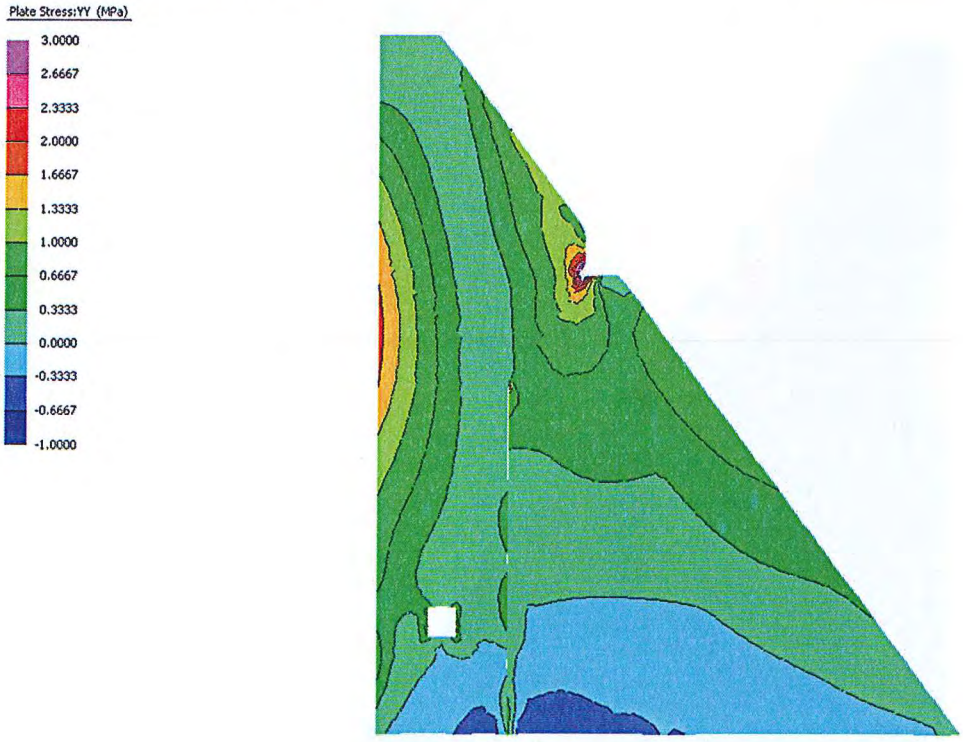
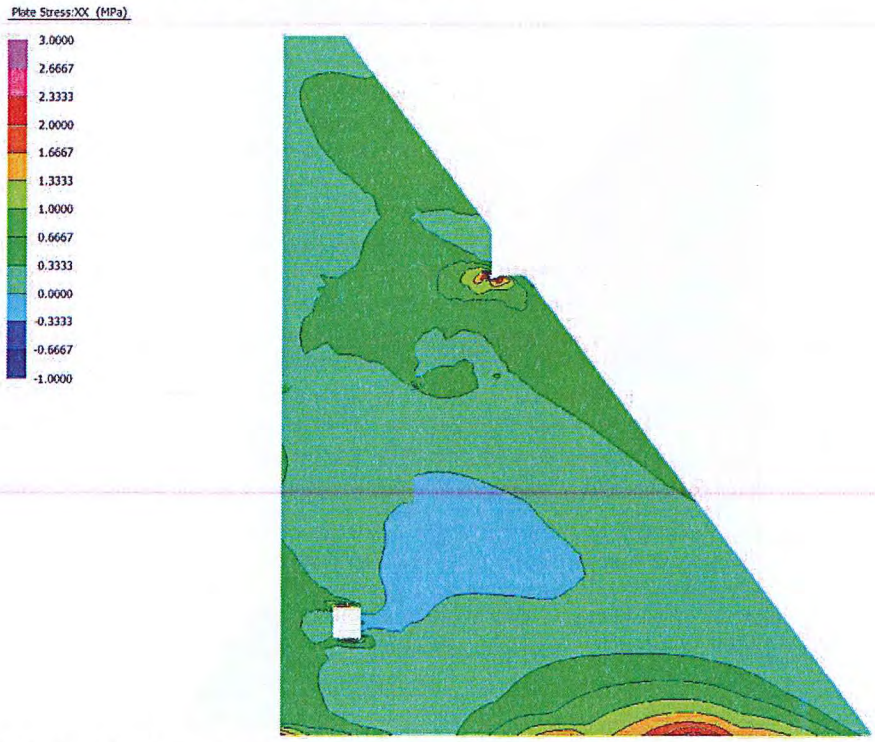


Figure 4.34 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress



SMadre-4734 Maximum Design Earthquake

Figure 4.35 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

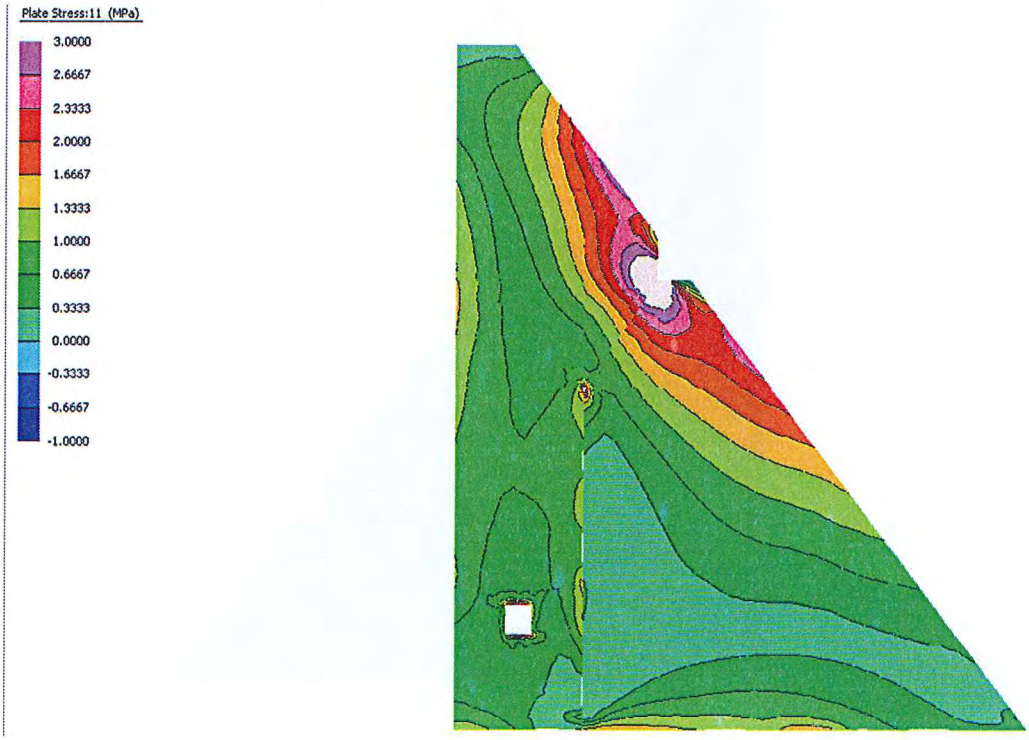


Figure 4.36 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

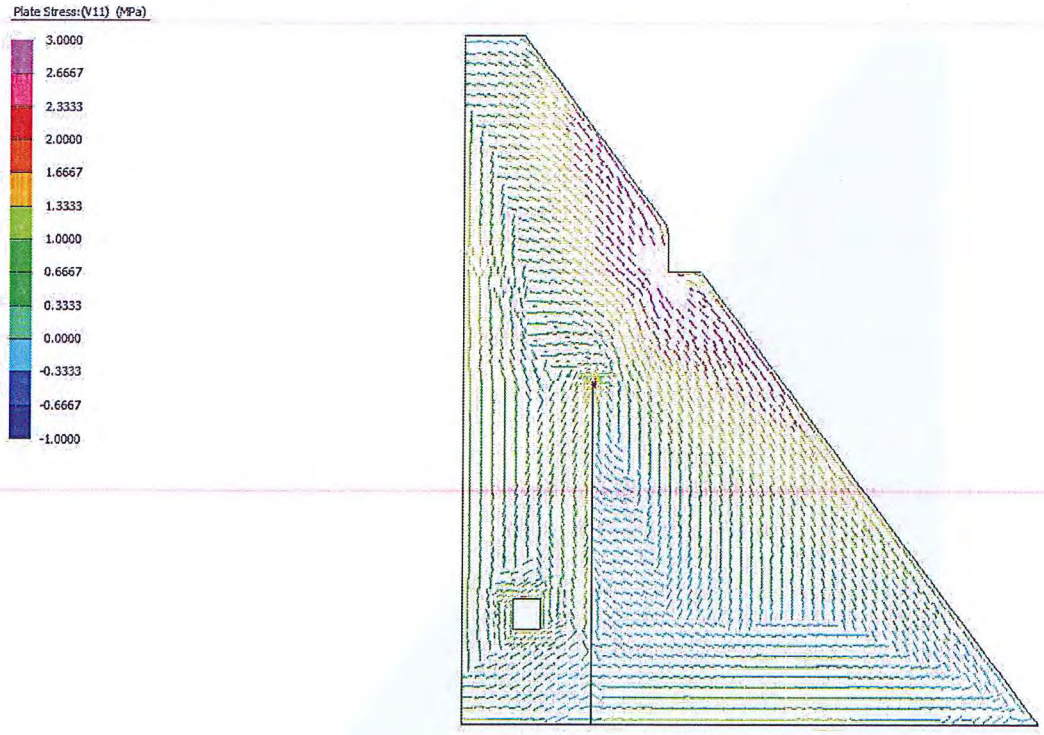


Figure 4.37 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Vertical Stress

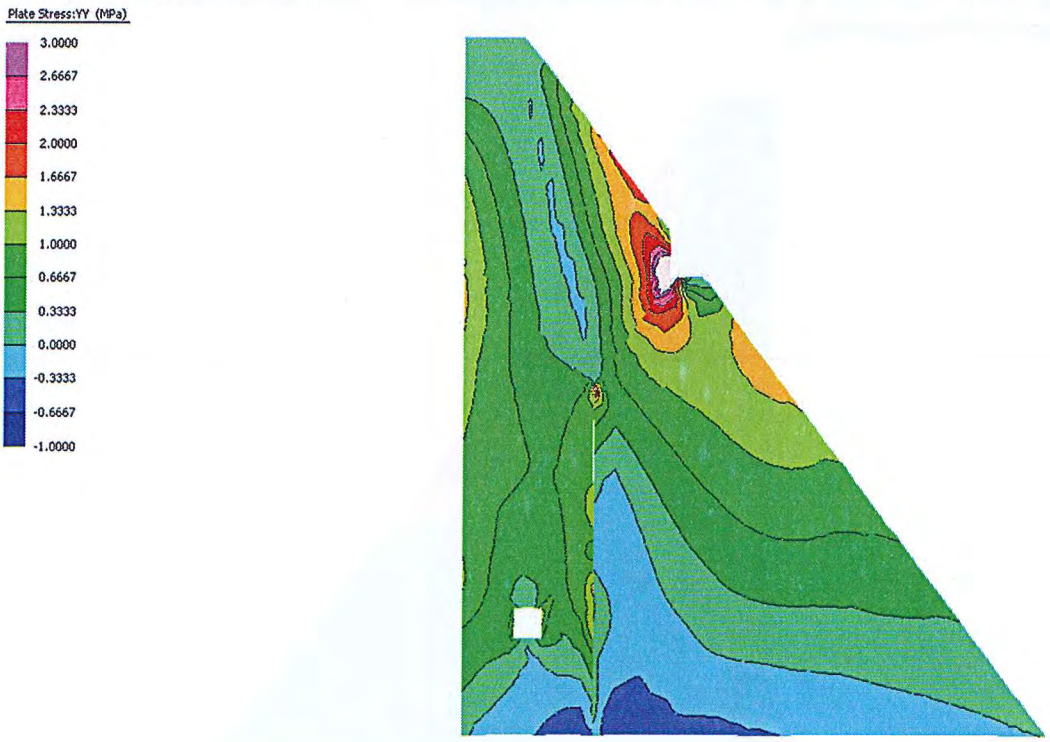


Figure 4.38 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

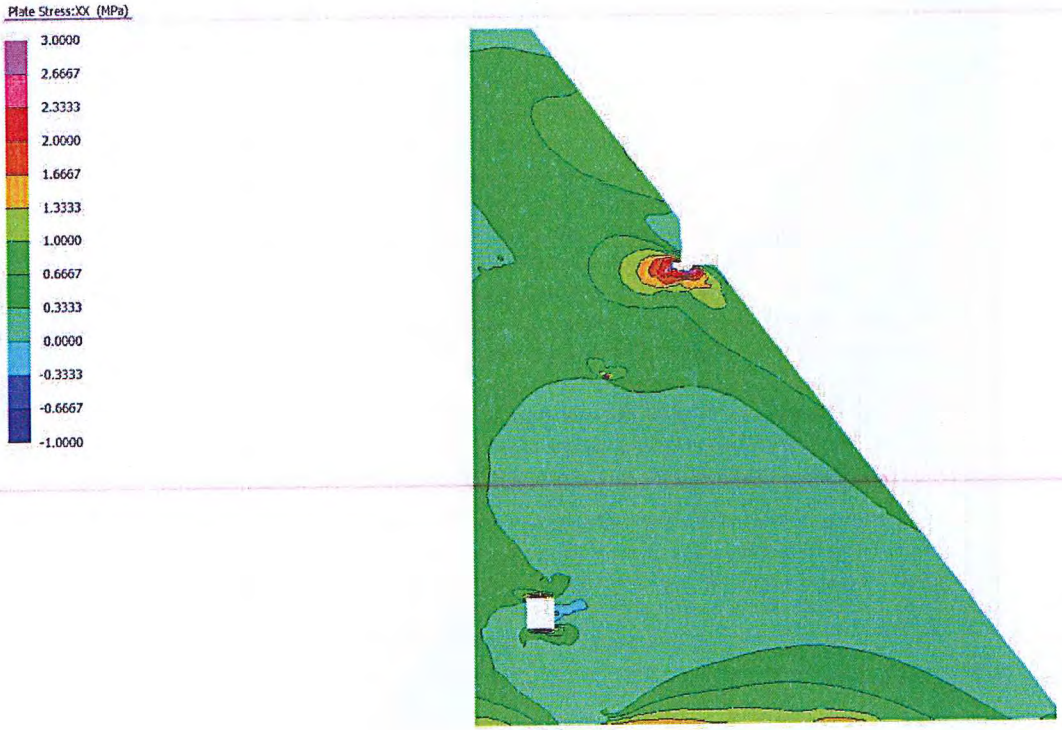


Figure 4.39 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

Figure 4.40 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

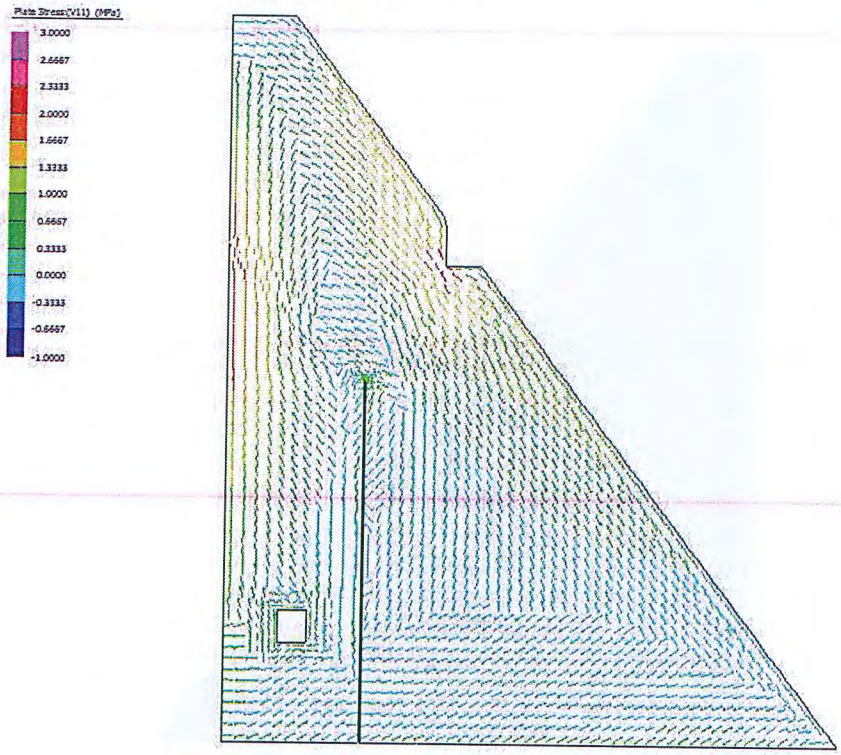


Figure 4.41 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Vertical Stress

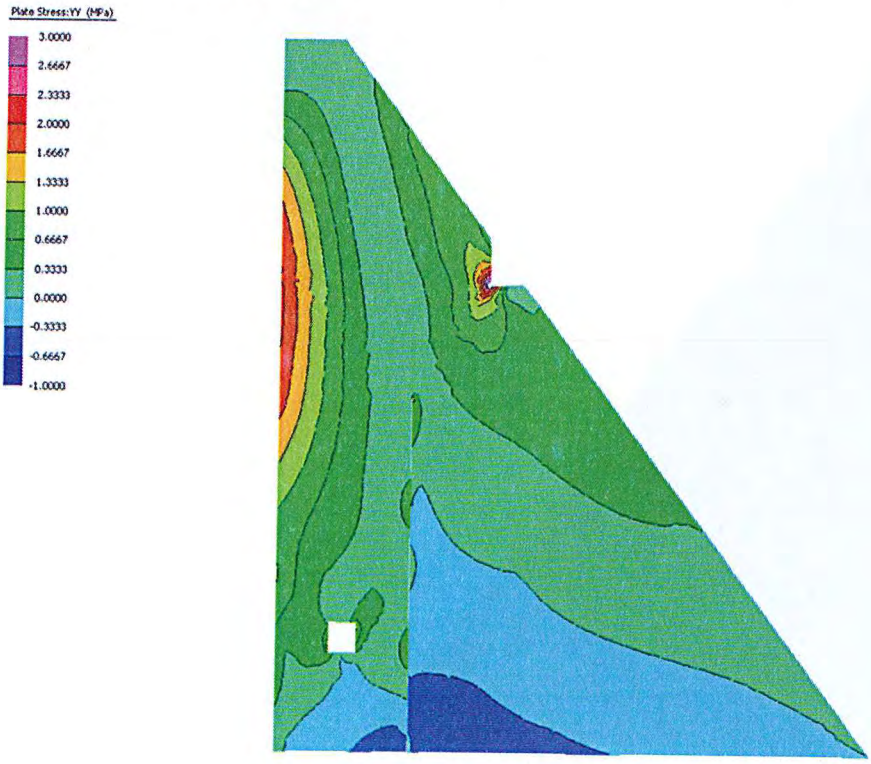


Figure 4.42 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

4.3.2 Displacement charts

North529 Maximum Design Earthquake

Figure 4.43 NORTH529 – East & Vertical Components – Base Residual Horizontal Displacement

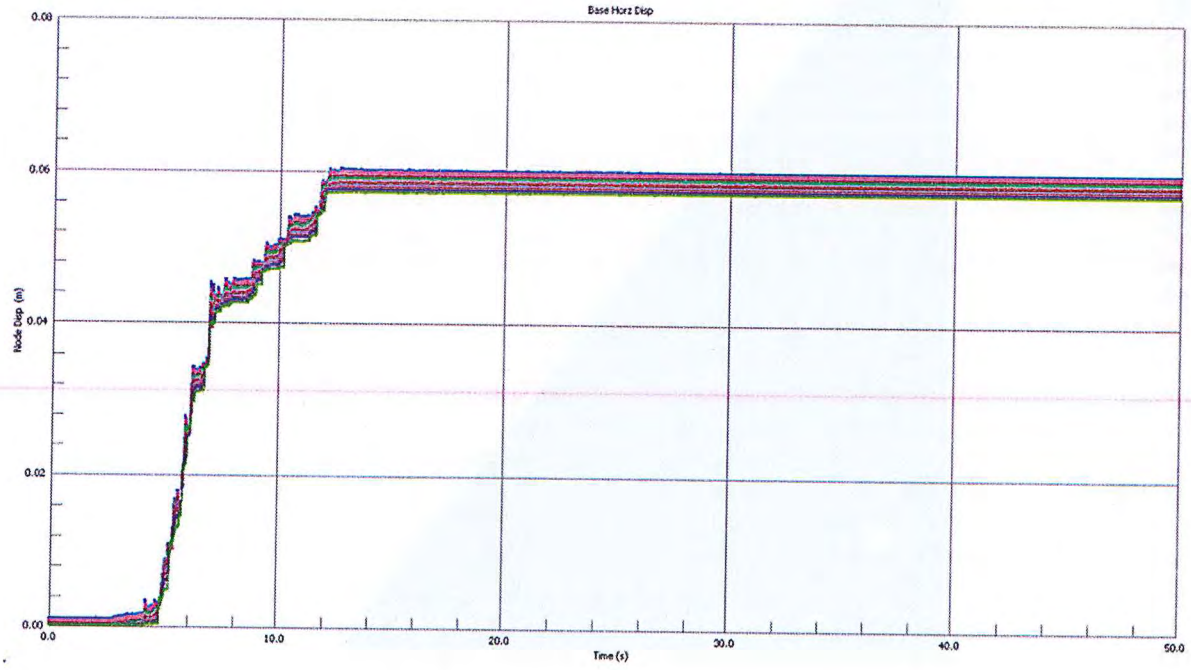
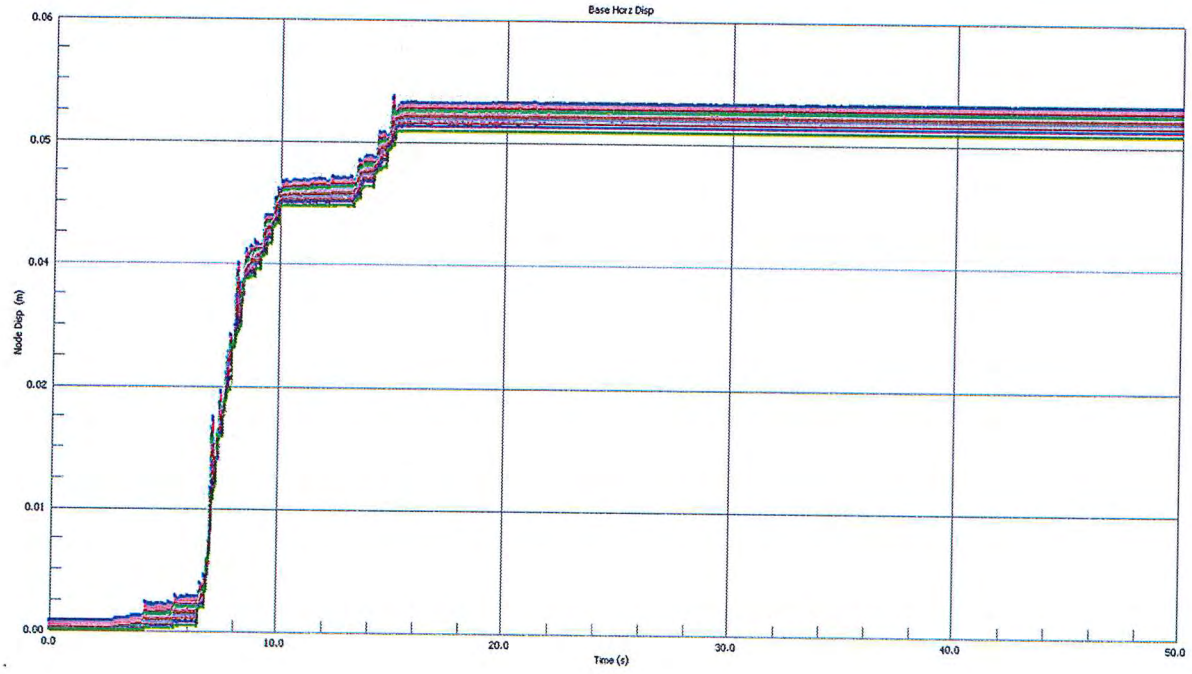


Figure 4.44 NORTH529 – North & Vertical Components – Base Residual Horizontal Displacement



North-Won Maximum Design Earthquake

Figure 4.45 NORTH-WON – South & Vertical Components – Base Residual Horizontal Displacement

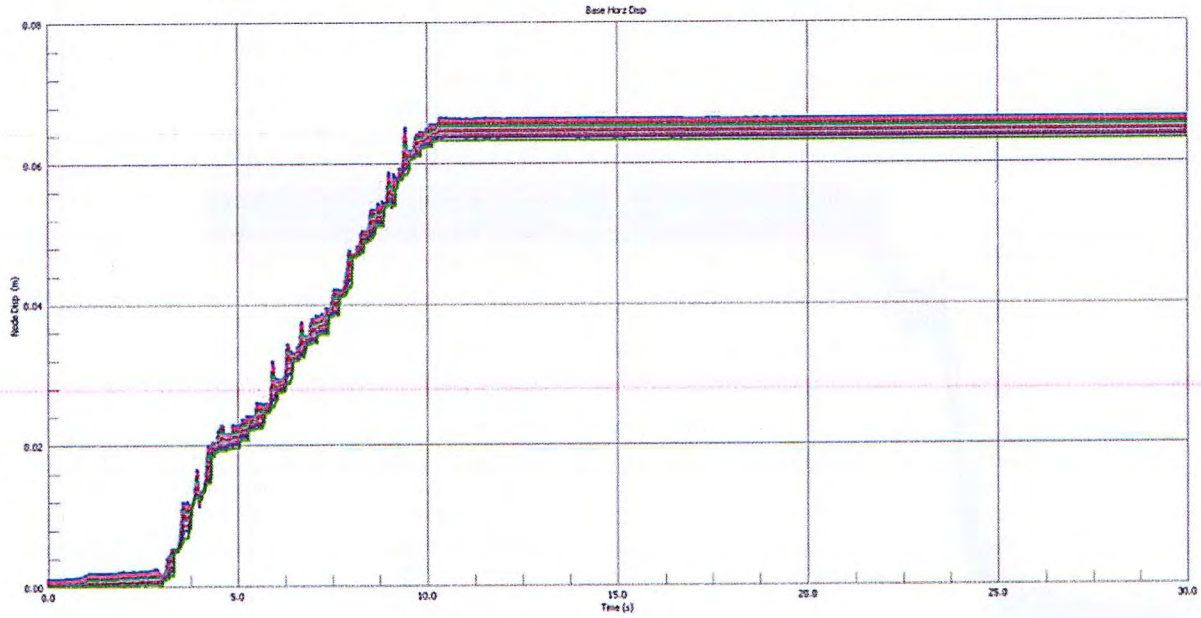
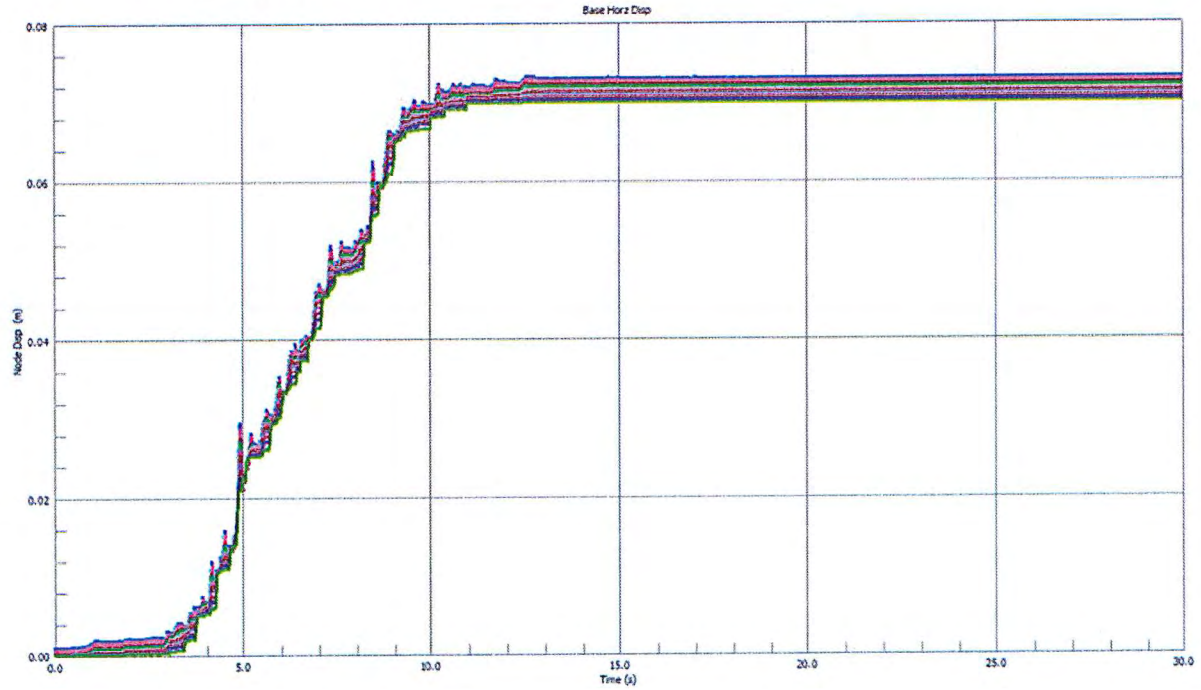


Figure 4.46 NORTH-WON – West & Vertical Components – Base Residual Horizontal Displacement



SMadre-4734 Maximum Design Earthquake

Figure 4.47 SMADRE-4734 – North & Vertical Components – Base Residual Horizontal Displacement

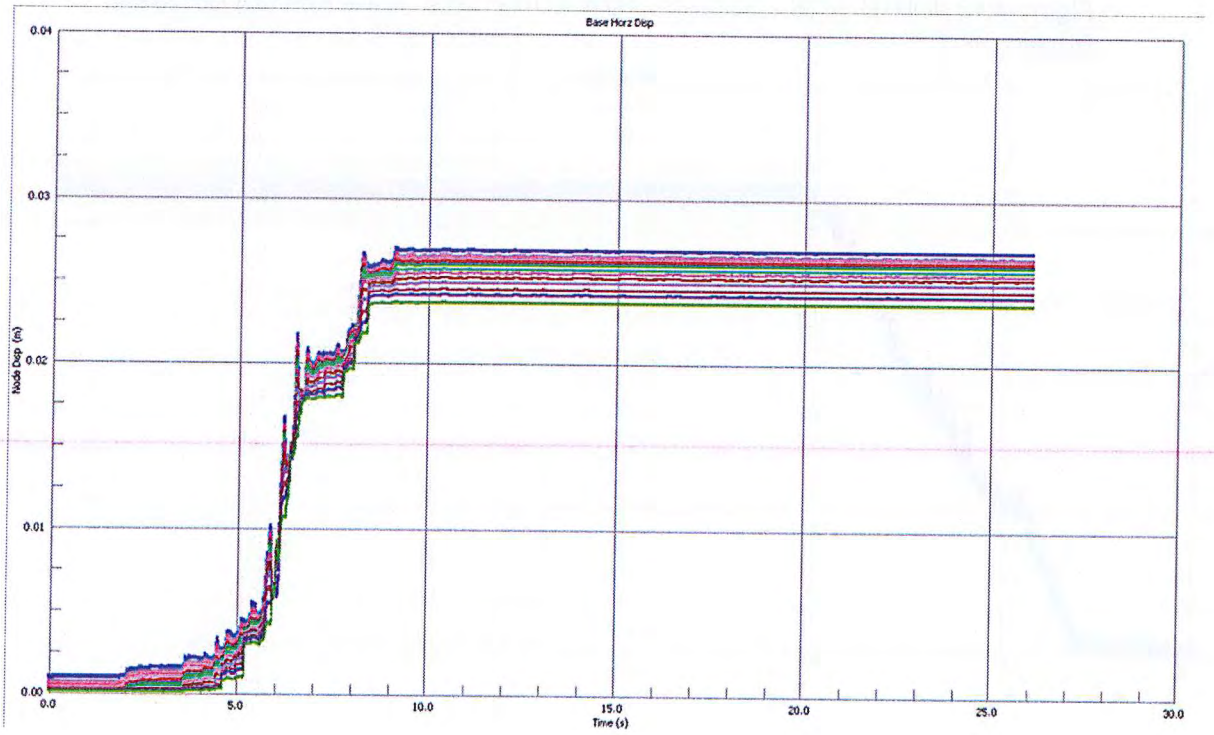
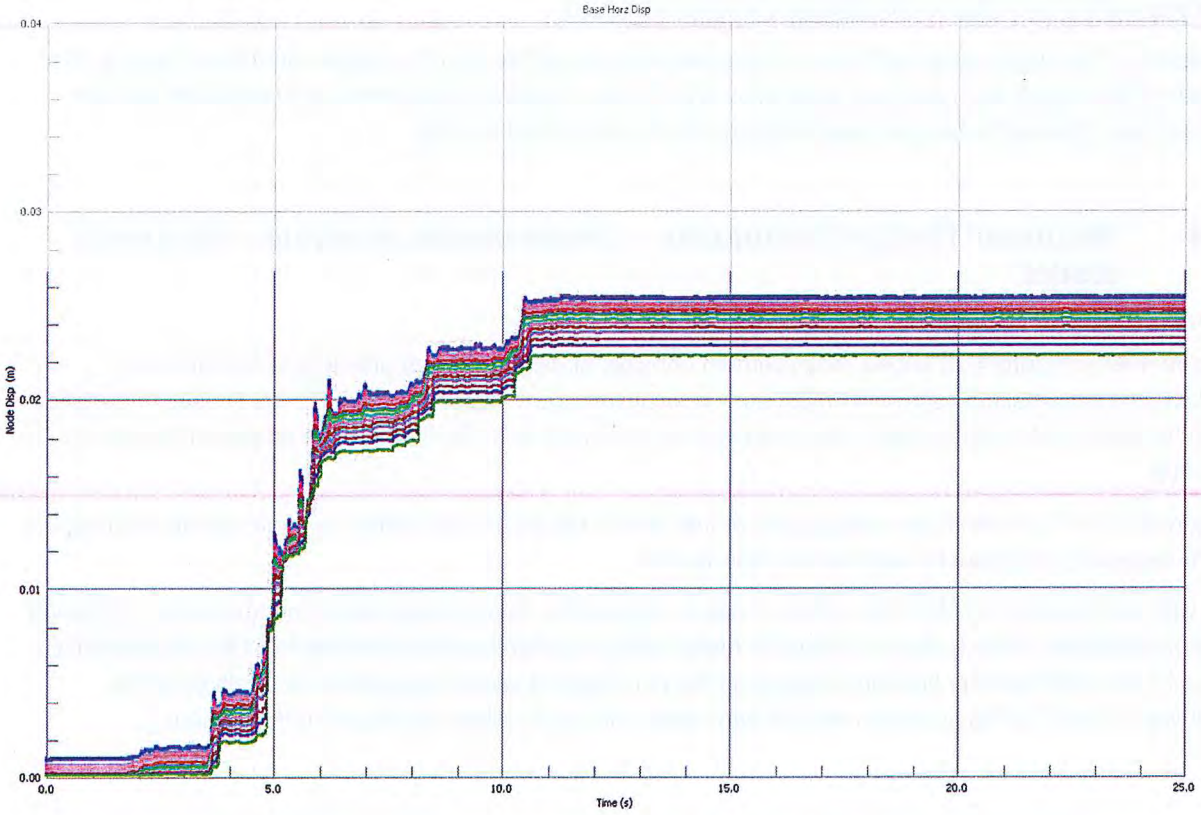


Figure 4.48 SMADRE-4734 – West & Vertical Components – Base Residual Horizontal Displacement



4.3.3 Discussion – MDE Events – Linear Elastic Model

As previously mentioned the linear analysis for the MDE load cases was undertaken to assess if the assumed crack was likely to propagate and if so which direction would be the most likely. The most likely crack path could then be included in further non-linear analysis. As with the OBE events the MDE linear model results (Figure 4.19 to Figure 4.110) typically show lesser magnitude stresses then the previous linear analysis on the uncracked dam section but are similar in both magnitude and shape to the original non-linear seismic analysis of the uncracked dam. This is with the exception of the area around the aerator step which shows concentrations of high tensile stress. Previous seismic analysis did not include modelling the unfilled aerator step on the downstream face. The magnitude of the stresses at the aerator step has been partially discounted as this step will be largely filled with concrete tied into the dam structure and therefore this irregularity within the downstream face of the dam will be less prone to attract stresses of such a magnitude. However as with the previous analysis there are significant areas of high stress present within all of the MDE load case results. For all of the MDE cases it was decided, based on the magnitude and the location of overstressed areas of the dam cross section, that the most likely cracking to occur would be horizontally along the lift joints between the upstream and downstream faces of the dam. These stresses were also observed to be significantly high close to the elevation of the tip of the assumed crack (RL 510.8). As such it was decided that further non-linear analysis would be undertaken for the MDE events with the inclusion of a horizontal crack from upstream to downstream which would intercept the tip of the assumed vertical crack at RL 510.8.

The inclusion of the horizontal crack is considered conservatives as the more likely behaviour is the development of a series of partial depth horizontal cracks which would provide adequate stress relief that the development of a full depth horizontal crack would not occur.

In addition, the displacement of the non-linear elements along the dam foundation interface (Figure 4.43 to Figure 4.48) ranged from approximately 25 mm to 70 mm. These displacements are consistent with the magnitudes observed in the previous analyses for the uncracked models.

4.4 Maximum Design Earthquake – Linear elastic Analysis – Abutment Model

4.4.1 Stress Envelopes

Figure 4.49 to Figure 4.72 shows the maximum principal stress, maximum principal stress direction, maximum horizontal stress and the maximum vertical stress envelopes for the MDE load cases undertaken with the abutment model including the assumed vertical crack from RL 510.8 to the abutment foundation at RL 506.

Figure 4.73 to Figure 4.78 provides graphs of the relative displacement of the non-linear elements along the dam foundation interface for each of the MDE events.

As with the maximum section the vertical crack is assumed to have propagated to the foundation. However this is considered to be a likely scenario for these sections given the short distance from the foundation to RL 511.3 m AHD and the previous analysis of the non cracked section indicated that relatively large (between 1 and 2 MPa) upstream downstream tensile stresses will be developed in this region.

Figure 4.49 NORTH529 – East & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

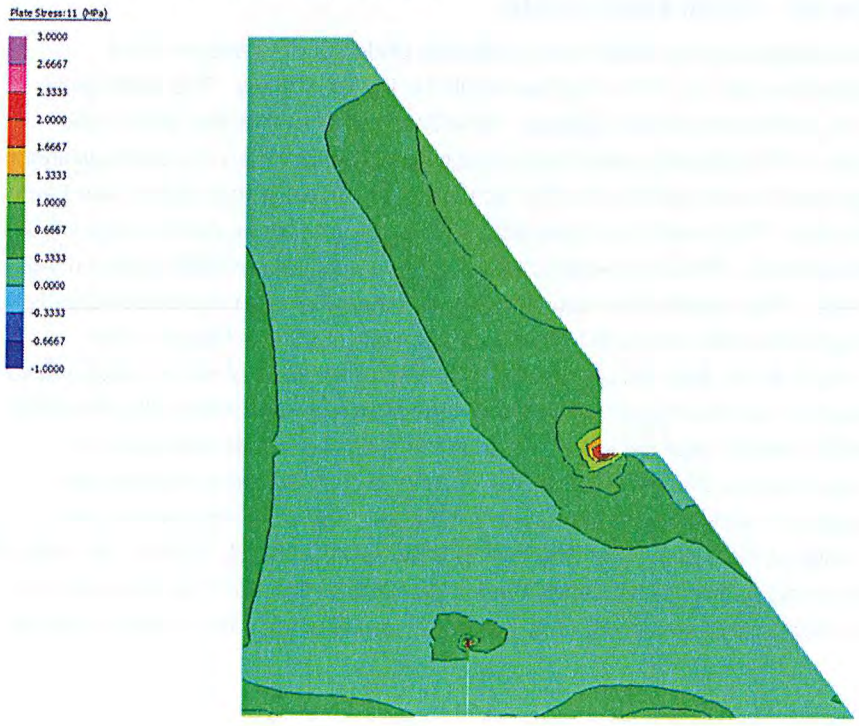


Figure 4.50 NORTH529 – East & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

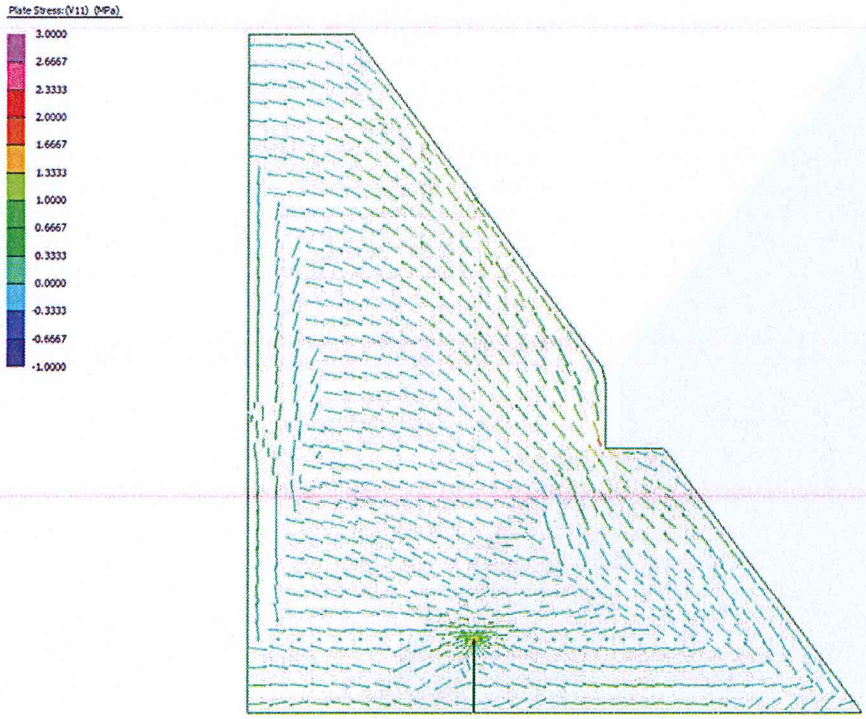


Figure 4.51 NORTH529 – East & Vertical Components – Maximum Stress Envelope – Vertical Stress

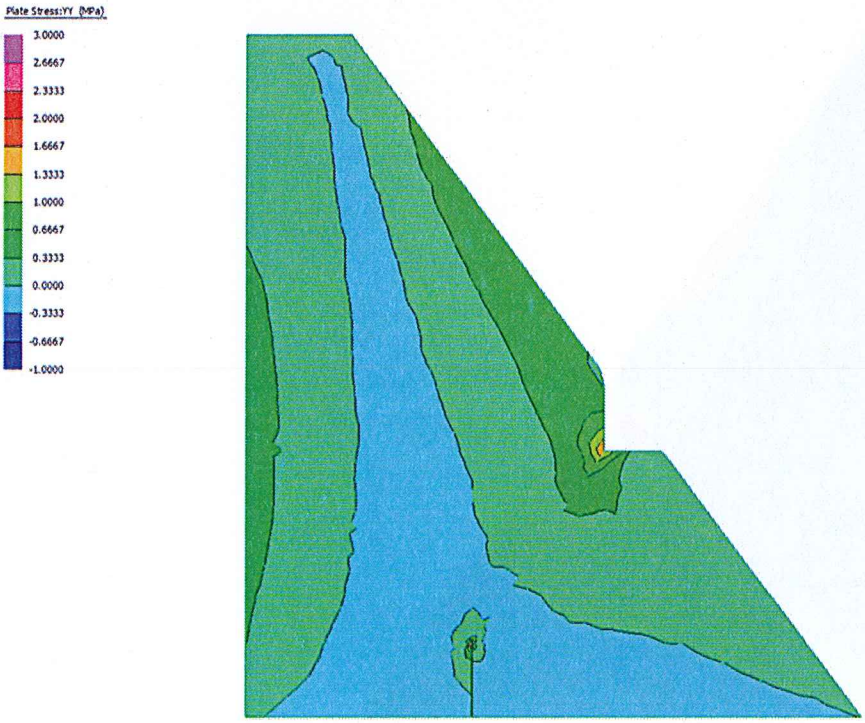


Figure 4.52 NORTH529 – East & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

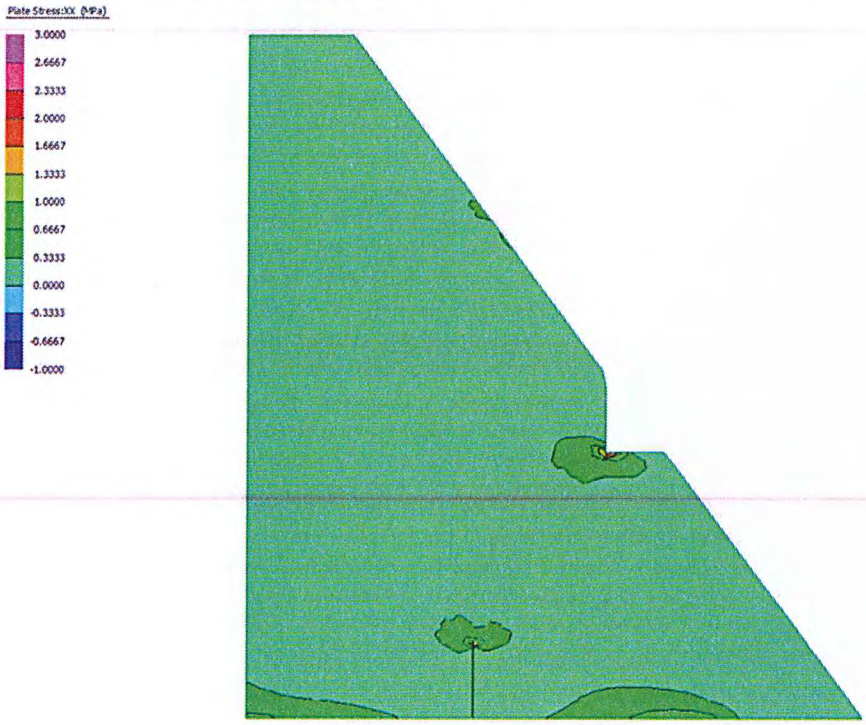


Figure 4.53 NORTH529 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

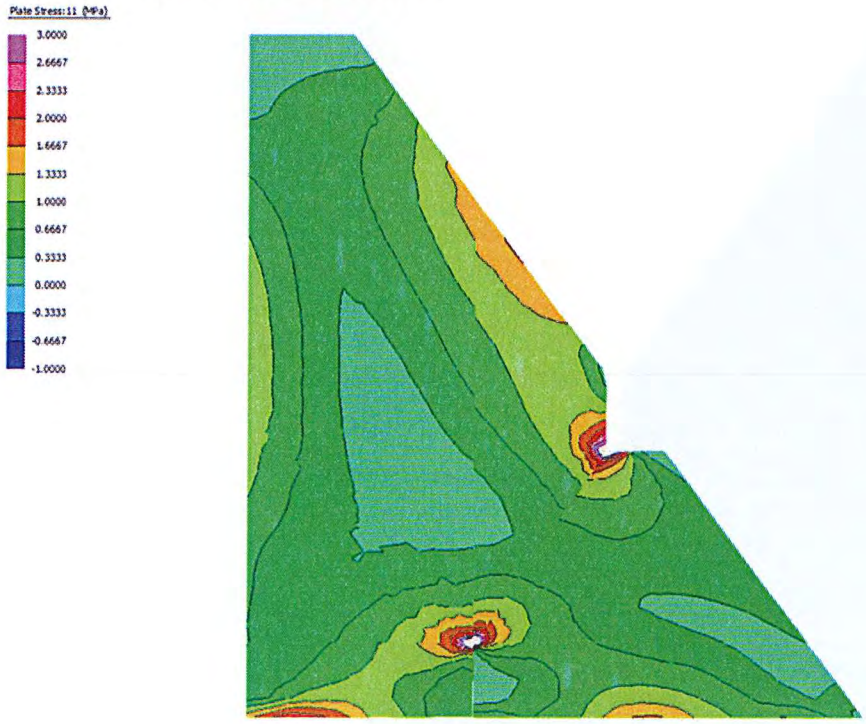


Figure 4.54 NORTH529 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

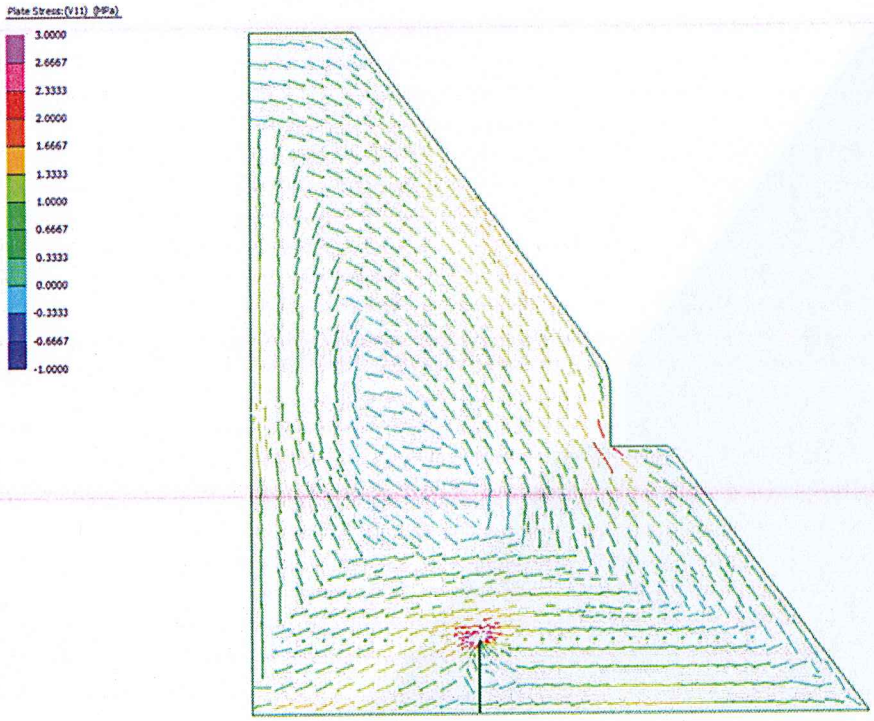


Figure 4.55 NORTH529 – North & Vertical Components – Maximum Stress Envelope – Vertical Stress

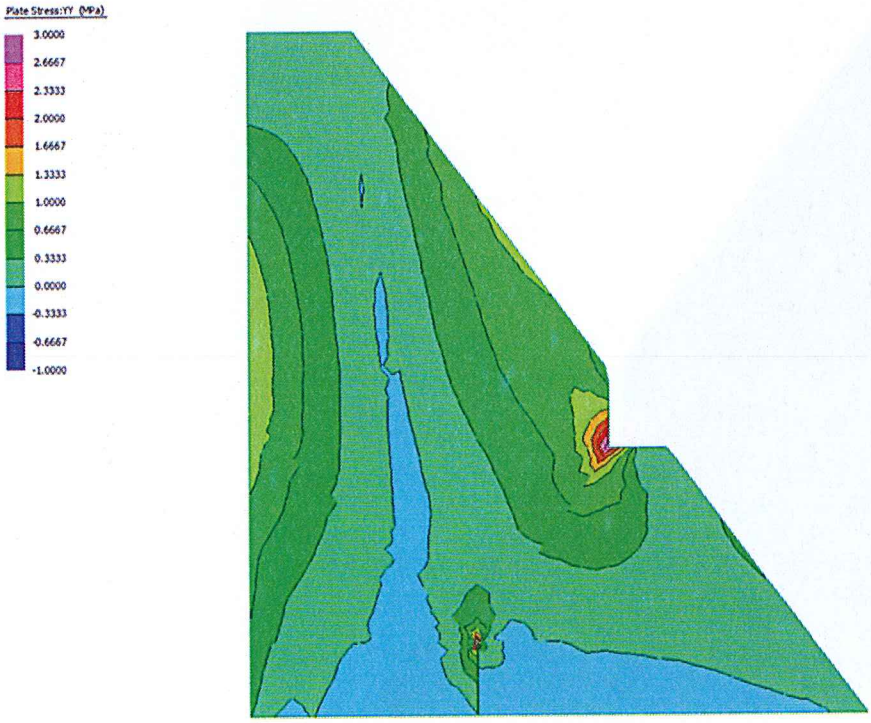


Figure 4.56 NORTH529 – North & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

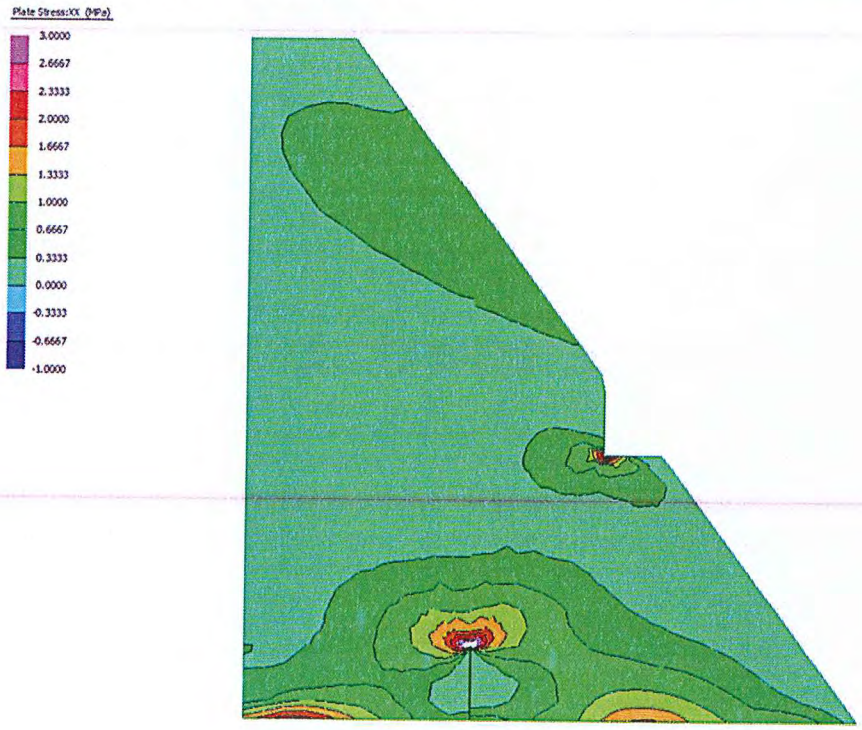


Figure 4.57 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

Figure 4.58 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

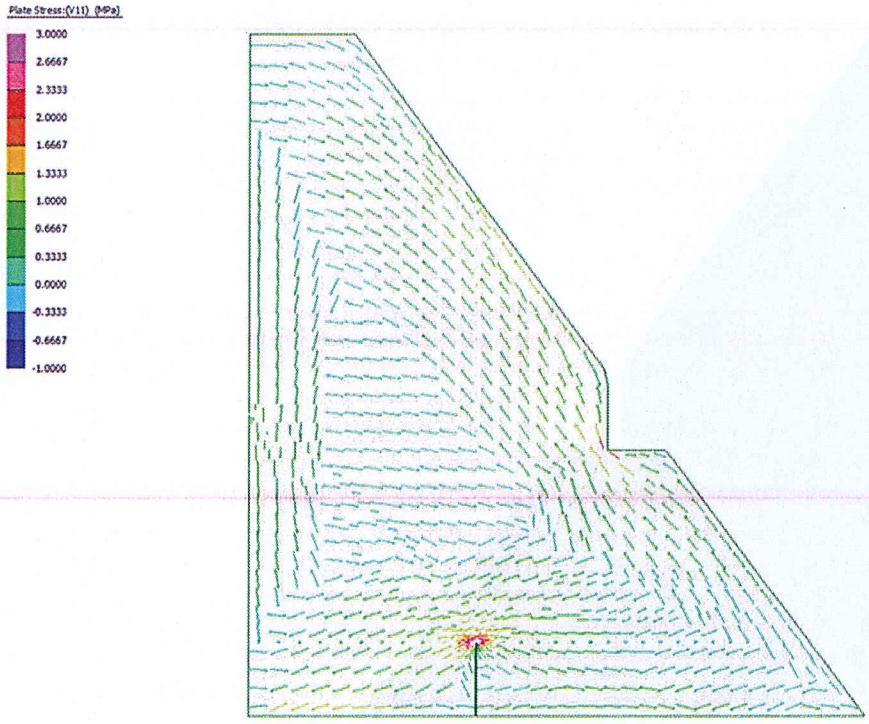


Figure 4.59 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Vertical Stress

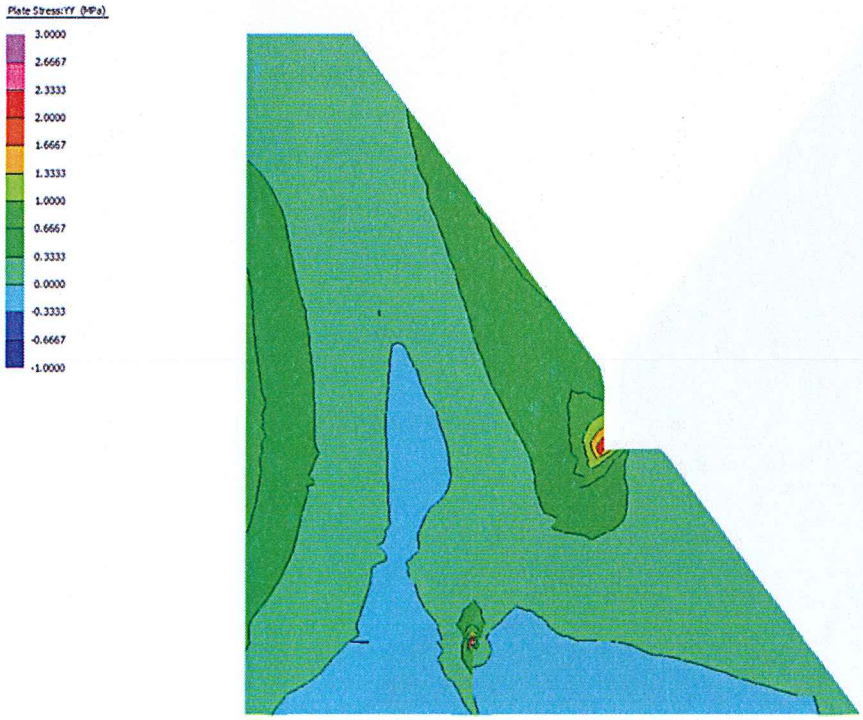


Figure 4.60 NORTH-WON – South & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

Figure 4.61 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

Figure 4.62 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

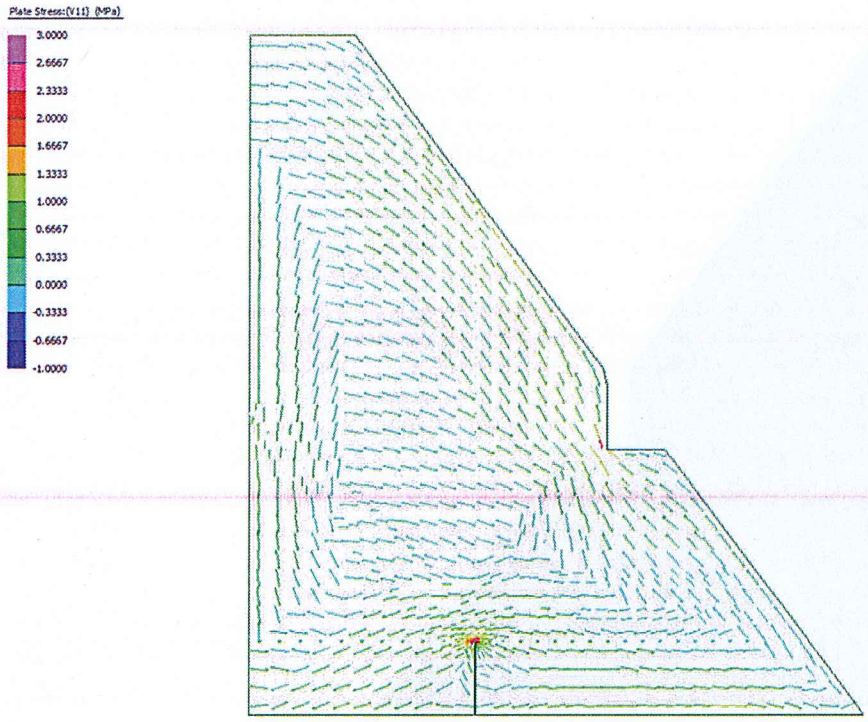


Figure 4.63 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Vertical Stress

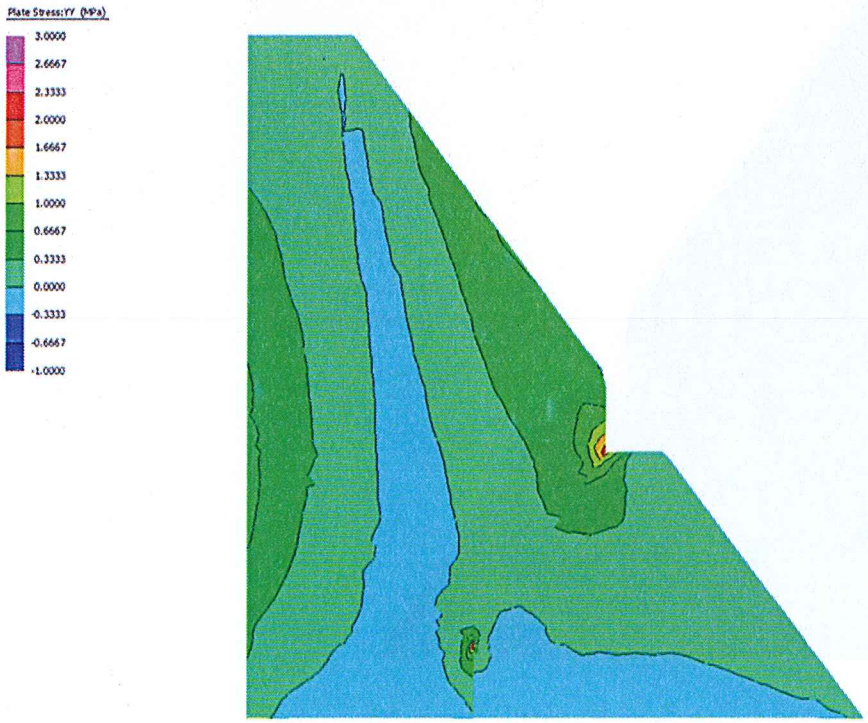


Figure 4.64 NORTH-WON – West & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

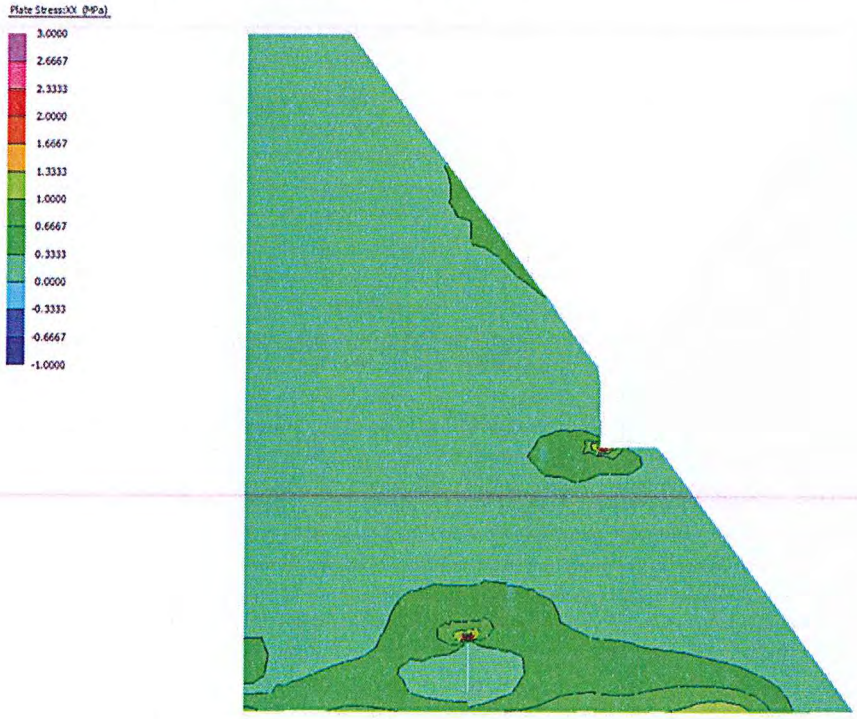


Figure 4.65 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

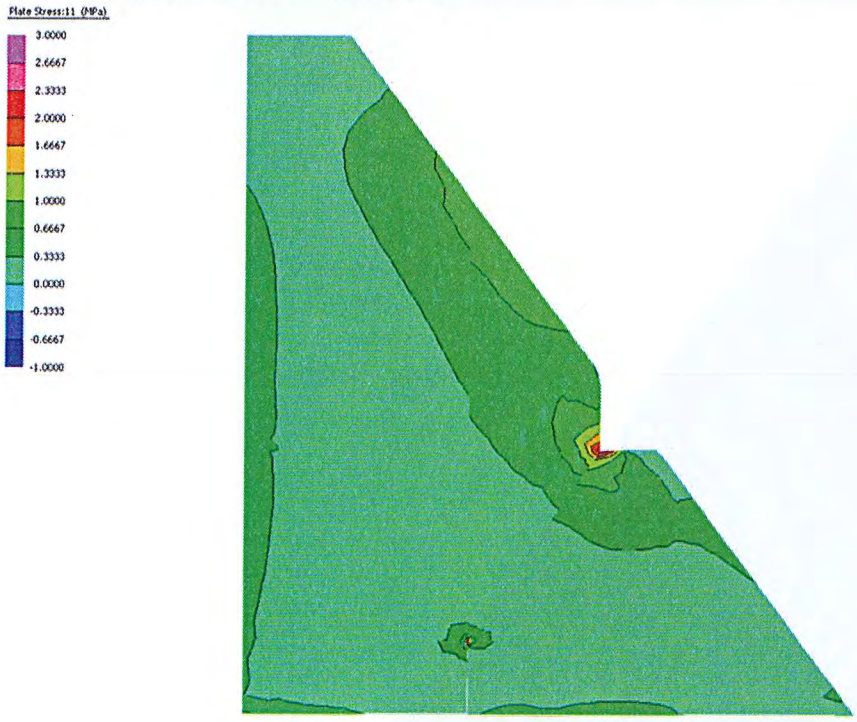


Figure 4.66 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

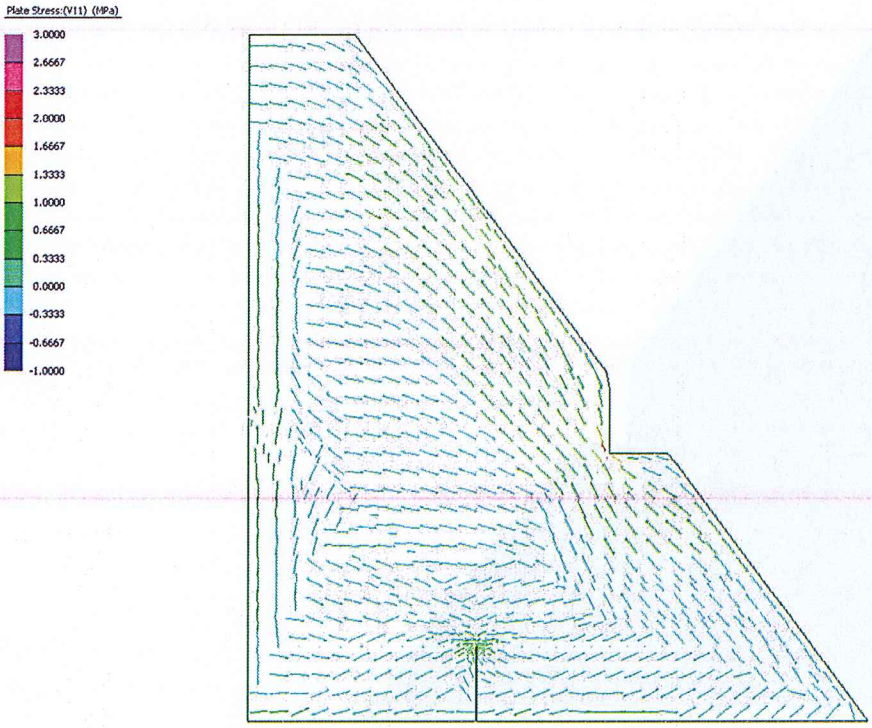


Figure 4.67 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Vertical Stress

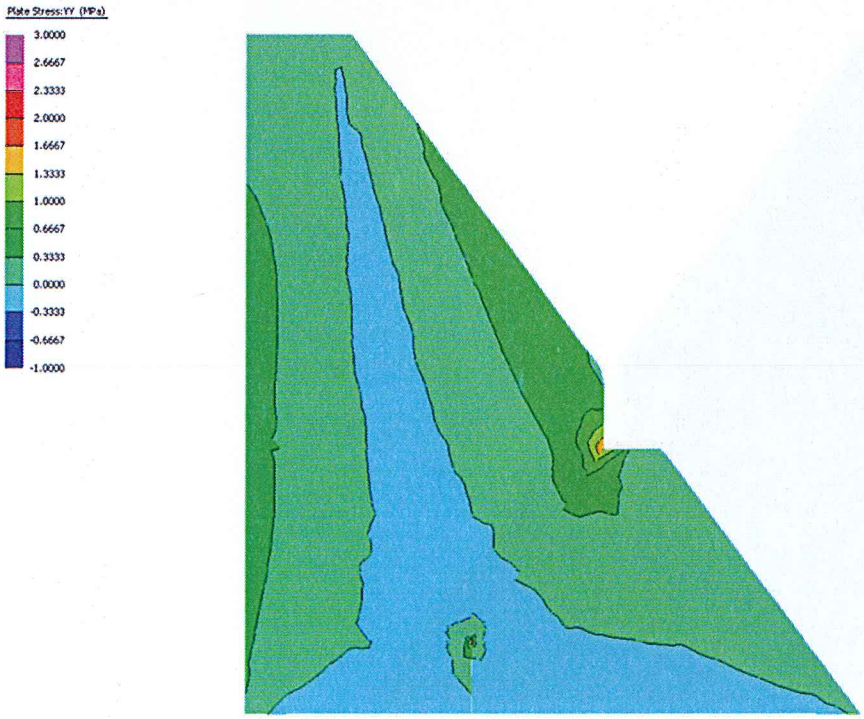


Figure 4.68 SMADRE-4734 – North & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

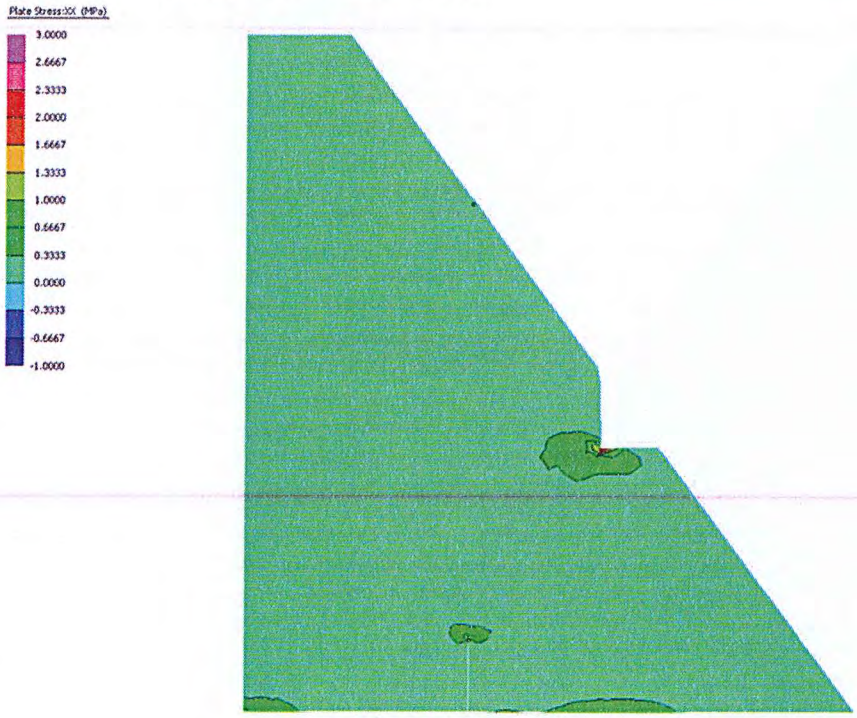


Figure 4.69 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress

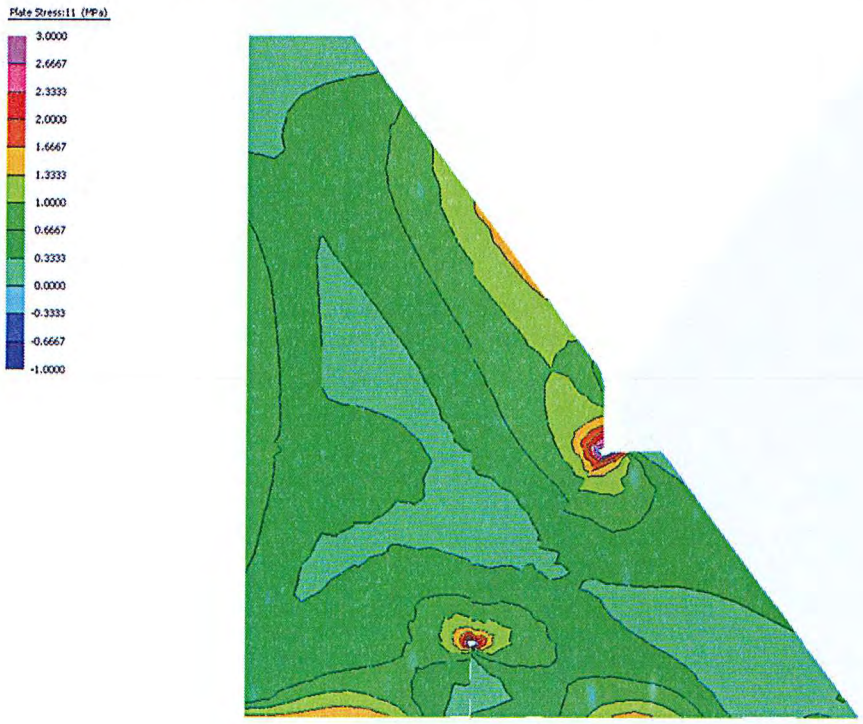


Figure 4.70 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Maximum Principal Stress Direction

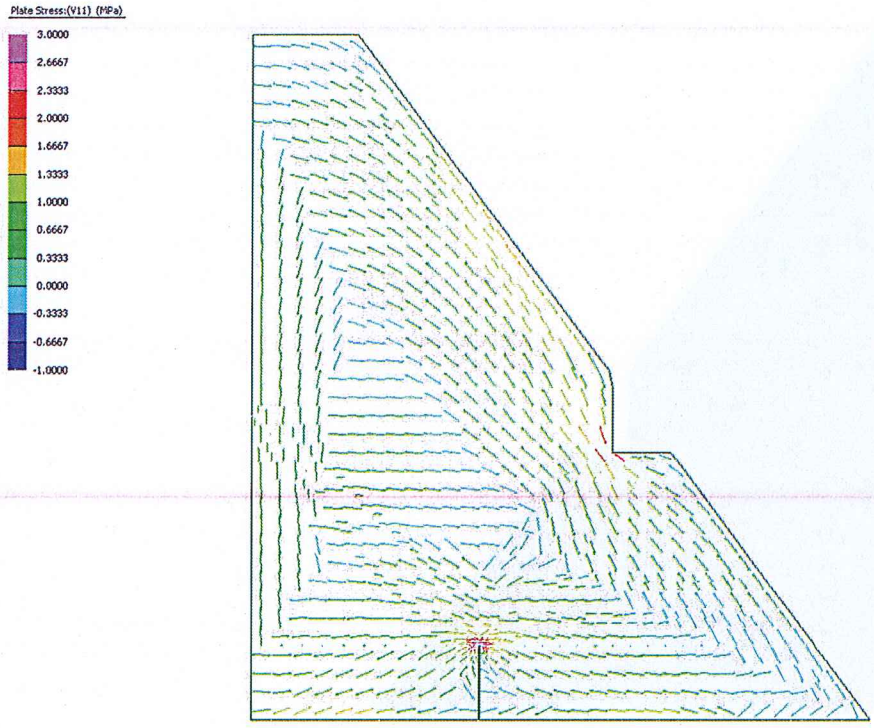


Figure 4.71 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Vertical Stress

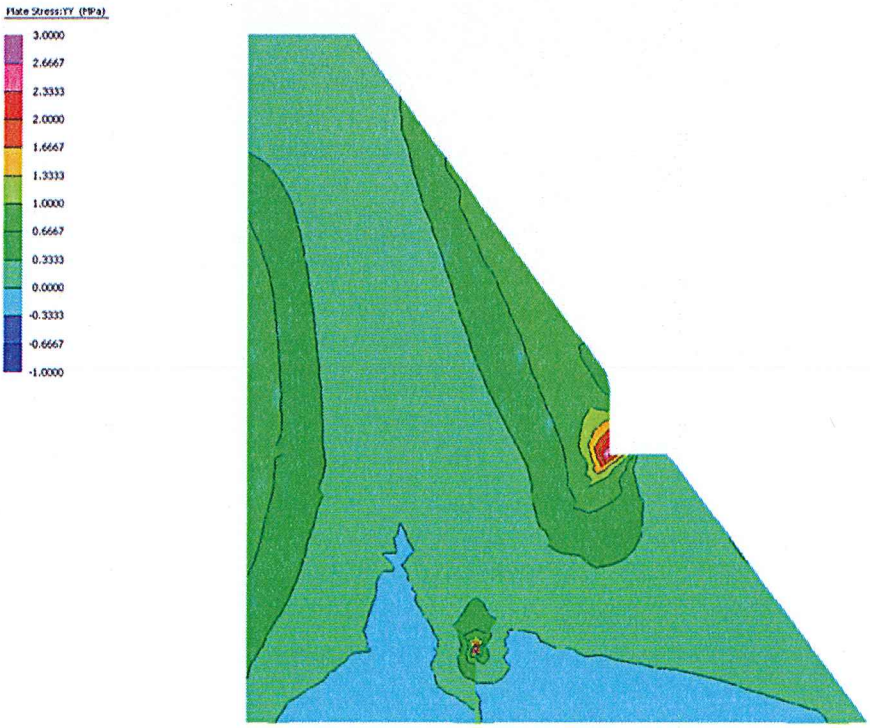


Figure 4.72 SMADRE-4734 – West & Vertical Components – Maximum Stress Envelope – Upstream Downstream Stress

4.4.2 Displacement charts