EXECUTIVE SUMMARY

ENGINEERING, GEOLOGICAL, GEO-HAZARD ASSESSMENT REPORT

The Engineering, Geological and Geohazard Assessment Report (EGGAR) is a requirement by the Department of Environment and Natural Resources (DENR) for Environmental Compliance Certificate (ECC) applications involving subdivisions, housing, and other land development and infrastructure projects. The implementing guidelines for the formulation of the EGGAR is covered by DENR Administrative Order (DAO) No. 2000-28, and the Mines and Geosciences Bureau (MGB) Memorandum Circular No. 2000-33, which took effect 14 March 2000. The proclamation of the EGGAR is pursuant of the government’s objective “to ensure the suitability and safety of a project site proposed for development.”

The EGGAR Scoping Process was initiated by NIA Regional Office VI in compliance to MGB Memorandum Circular No. 2002-43. The scoping commenced with the conduct of Geological Site Scoping (GSS) on October 23 to 25, 2012 by MGB Region VI Senior Science Research Specialist and Geologist Ms. Leilanie O. Suerte, PhD., and Science Research Specialist I Ms. Ma. Lucille V. Fuentes. The objective of the GSS was to identify geologic hazards relevant to the project. The results of the MGB survey are contained in MGB GSS Report dated November 2012, which served as the basis for the preparation of EGGAR report.

Surface mapping of exposures at the project sites was done at the proposed Jalaur High Dam site (Brgy. Garangan, Calinog), Jalaur Afterbay Dam site (Brgy. Acalaga-Garanga, Calinog), existing access road to the High Dam site (Brgy. Garangan, Calinog), north and south rim of the proposed Jalaur Reservoir area (Brgy. Garangan, Cahigon, Binulusan Pequeno of Calinog), proposed Alibunan Catch Dam site (Brgy. Alibunan and Toyungan of Calinog), proposed Alibunan Reservoir (Brgy. Cahigon, Calinog), and portion of the High Line Canal (municipality of Calinog, Lambunao, Badiangan, Cabatuan, Almodian, Leon and Tigbauan). Exposures were observed along trails and road cuts, and from erosion and landslides. In contrary, outcrops in the dam sites that are situated on very steep and dangerous sites were not examined. The proposed Jalaur High Dam and Afterbay Dam sites and vicinity were accessed via the road using 4-wheel and 2-wheel vehicle and trekking along the Jalaur river from downstream. A bamboo raft was also used in accessing outcrop across deeper level of the Jalaur River. Observation on the Jalaur Reservoir was only limited on the north and south rim while on the Alibunan Reservoir was done along the submerge area. On the proposed High Line Canal, observations were made on some stretches of the canal line, on the topography and nearest outcrops. The geology of adjacent areas not covered in the fieldwork has been compiled from previous works of NIA (1976) and MGB (2012)

Fieldwork was done in November 7-8, 11-30, 2013 and January 22-February 1, 2014 which includes coordination with NIA personnel, field work at the Jalaur High Dam and Reservoir rim, Jalaur Afterbay, Access Road to the Jalaur High Dam, Alibunan Catch Dam and Reservoir, and sites along the High Line Canal, and logging of drill cores at the NIA-VI Regional Office. A hand-held Garmin™ eTrex Venture HC GPS receiver, with 3-5m horizontal accuracy, was used in locating.
observation points. Post-field processing of survey points was done to correct mislocated/misplaced points as detected when plotted in Goggle Earth™.

The JRMP II is considered the very first multipurpose project in the Visayas Region and has been the subject of much speculation from the people of Iloilo who had been long expecting its implementation. The study has received strong support from the Municipal and Provincial Government Officials. From the revised development plan (Korean Exim Bank, Nov 2011), the Project is envisioned to provide: year-round irrigation water to an estimated 31,840 ha of agricultural land that include the rehabilitation of 22,340 ha service area covered by the five (5) existing irrigation systems in the Province of Iloilo; generate about 6.6 Megawatts of hydro-electric power; and supplement the supply of water for domestic and industrial use for the seven (7) nearby municipalities including Iloilo City. Other incidental benefits consist of flood mitigation (flood control) to address recurring destructive floods in the Province and promote eco-tourism development in the dam/reservoir area. Further, it would generate thousands of employment opportunities towards economic enhancement of Iloilo people particularly the project-affected-families, stakeholders and other beneficiaries of the Project. The Project, likewise, aims to address the Government’s thrust to bring the people closer to the development mainstream through increased irrigable lands and thereby helps upgrade the economic conditions and standard of living of the project-affected families, stakeholders and other beneficiaries of the Project.

The estimated total target area of 31,840 ha for development are distributed within the 23 municipalities and one component city in the Province of Iloilo. These areas are equitably spread in the southern and northeastern portions of Panay Island and are located centrally in the Western Visayas. About 70% of these areas or 22,340 ha are currently planted to rice and are covered by the Jalaur, Suage, Aganan, Sta. Barbara and Sibalom River Irrigation Systems. The 7,000 ha of new area and 2,500 ha planted to sugarcane are presently rainfed areas to be provided with new irrigation facilities and thus, would also be served with year-round irrigation after Project completion. The target service area cover parts of 24 out of 43 municipalities of Iloilo.

Specifications of the 3 selected dams extracted from the original design of the previous FS 1976 and was revised during the 2011 validation by the KRC Consortium.

Jalaur High Dam located at the upstream of the eastern Jalaur River in the Antique ranges in Panay (North latitude 11° 10’ 32”, East longitude 122° 27’ 30’’); Foundation conditions can support the dam structure and the reservoir weight. The dam axis is bended by 60 in order to support the loads at both sides of the dam; Dam type is Roller Compacted Concrete (RCC) Dam; Dam height is 106.0 m; Length of dam is 225.0 m; Installation of 80 m overflow spillway at the center of the dam (Flip bucket type, discharge Q=1,940 m³/sec - 1,000 year frequency) and Installation of powerhouse in the left side of the dam, 60m downstream of the dam. (6.6 MW, plant discharge Q=11.64 (2 x 5.82) m³/s.

Proposed Jalaur Afterbay Dam located at the proposed High Line Canal (Station 0+000 of High Line Canal), 1.9 km downstream of Jalaur High Dam (North latitude 11° 10’ 9.47”, East longitude 122° 28’ 1.09’’); Temporary storage of 0.29 MCM (106 m3) for water supply to canal and 12 hours power generation; Dam type is Faced Symmetry Hardfill Dam (FSHD); Dam height is 40.0 m; Length of dam is 148.0 m and Installation of 80 m overflow spillway at the center of the dam. (Stilling basin type, discharge Q=986 m³/sec - 100 year frequency)
Alibunan Catch Dam located at 80 m upstream of where Alibunan bridge will be built in Alibunan River (Station 3+480 of High Line Canal) (North latitude 11° 08' 47", East longitude 122° 27' 14""); Located at a gully with a width of 110 m and a riverbed level of El. 94 m.; Easy to acquire construction materials and good foundation condition for Hardfill type dam along the river. Dam type is Hardfill; Dam height is 24.3 m; Length of dam is 115.0 m and Installation of 50 m width overflow spillway at the center of the dam (Flip bucket type, discharge Q=698 m3/sec -100 year frequency).

High Line Canal was designed in accordance with NIA standards and for provision of structures and facilities capable of withstanding the adverse effect of climate changes. For more efficient water conveyance, the first 15 kilometers (km) which passes along hillside and unavoidable depression areas was designed as open channel with concrete canal lining to minimize seepage losses. Moreover, the right side of the High Line Canal is provided with operation and service road for maintenance purposes for farmers’ access to their farm lands, and for bringing their crop produce to the commercial areas or warehouse. It can support some 7,000 ha new paddy areas and 2, 500 ha of presently sugar cane area near the existing diversion dam at Jalaur River and could convey one (1) m3/sec for Metro Iloilo Water District (MIWD) domestic water supply and allocation for augmenting the existing water resource of the five (5) existing irrigation systems.

In Panay Island where the project site is situated, three major tectonic features were identified: the Northeast trending Tablas Fault, the east dipping Negros Trench on the west of the island and the two segments of the North-South trending West Panay Fault which transects the length of the Antique Range.

Results of hydrology analysis show that water supply is adequate and reliable to support the JRMP II. With the storage capacity of the proposed dam, the project would be able to support the irrigation requirements on a year-round basis. The threat of climate change is an inevitable factor in the environment, as well as the assurance of the stability of the dam. Re-assessment of hydro-meteorological data shows that there will be higher rainfall within the months of June to August, and less rainfall within the months of February to April. The dam will hold the excess water during the wet season which would be released during the dry season, hence, providing better opportunity to support agriculture and other uses when there is less rainfall. The proposed construction of the dams under the JRMP II is envisioned to provide benefits to wider population, however, several apprehensions arise among the general public. The apprehensions are influenced by the occurrence of recent calamities in Iloilo and in other parts of the country such as flooding in Iloilo, in Luzon and in Mindanao, and earthquake in Iloilo.

On the overall, it is assessed that the proposed project will provide more sustainable and hence more reliable water supply, given that water during wet season shall be stored and hence ensuring water supply during dry season. On the other hand, a fear is that in view of the storage of water, the flow downstream would be reduced, and hence deprive the present users of the water they used to have. The dams proposed under the project would ensure better and more reliable water supply due to the storage of water during wet/rainy season. The stored water would support agriculture, domestic water supply through bulk water, and power supply.

Geologic hazards are classified into three categories: fault related/seismic hazards, mass movements and volcanic hazards. Other Potential Adverse Environmental Impacts of Dams and
Reservoirs are submergence of some 780 hectares of land that would also require the displacement of people and their relocation. The reservoir dam will change the pattern of flows released downstream. Microclimatic changes may occur through varying humidity and this may affect crops and biodiversity downstream of the reservoir.

### SUMMARY OF POTENTIAL GEOHAZARDS AND RECOMMENDED MITIGATION MEASURES

<table>
<thead>
<tr>
<th>Geohazard</th>
<th>Potential Risk</th>
<th>Causative Factors</th>
<th>Impact</th>
<th>Mitigations Applied/Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Acceleration (intense ground shaking)</td>
<td>High</td>
<td>Earthquake Reservoir Trigger Earthquake</td>
<td>Slope failure, foundation failure</td>
<td>Seismic loading analysis performed for the Feasibility Study adapted a probable peak ground acceleration (PGA) of 0.24g based on statistical value of magnitudes should instead consider the magnitude of the most destructive earthquake. Adopting Ms 8.3 as the MCE and the West Panay Fault as the earthquake generator, a deterministic approach estimated PGA in the order of 0.30g for rocks. Site specific ground conditions and PGA should be given particular consideration in the final design of the infrastructures and facilities. The proposed structures should also adhere to design guidelines of local and international design standards. Review of previously acquired geotechnical borehole logs in addition to geotechnical evaluations to further refine the dam designs and to address the potential impact of seismic activity to the structures. Engineering measures to mitigate slope failures in subsurface excavations should be applied to reduce impact of seismic event. Monitoring instruments should be installed to verify the assumptions and conditions considered for the foundation and facility design. Visual inspection of the infrastructure and facilities after major earthquakes.</td>
</tr>
</tbody>
</table>

---

**Seismic Hazards**
Minor damaged to structure should be repaired immediately.

Reservoir triggered ground motion should in no case be greater than the MCE ground motion and the faults considered capable of triggering seismicity should be taken into consideration during the seismic hazard evaluation. Still the result might be the premature triggering of seismic events due to the impounding of the reservoir that would have occurred naturally at some longer time in the future. It is therefore justified in case of larger dams and storages located in seismically active regions and regions with high tectonic stresses to install a micro seismic network and to monitor the seismicity prior to, during and after impounding.

<table>
<thead>
<tr>
<th>Ground Rupture</th>
<th>Moderate to High Earthquake</th>
<th>Structure deformation (cracking of structure)</th>
</tr>
</thead>
</table>
| Although the project facilities are in sufficient distance from nearest active fault (West Panay Fault), the proponent should consider conducting a seismic imaging of the dam foundations and immediately in the vicinity of the dam areas to identify major possible structures/discontinuities not evident during the surface mapping. This may also confirm the presence/absence of the NW lineament identified in the tectonic map.

Continual geologic mapping during the excavation to map unrecognized and undetected structures during the surface mapping due to limitation of exposure brought about by inaccessibility of the outcrop, and rocks concealed by vegetation and weathered profile/zone.

Modification of engineering design should be considered as the need arises brought about by the changes in the nature and geotechnical properties of lithology as they are uncovered during the excavation.

Visual inspection of the TSF after major earthquakes.
Minor damaged structure should be repaired immediately.

| Liquefaction | Low | Earthquake | Settlement, deformation structure | Recommendations on seismic loading analysis as presented above should be performed. Design crest elevation should provide sufficient freeboard to protect against overtopping caused by vertical settlement that might occur during the MCE. Visual inspection of the infrastructure and facilities after major earthquakes.

Minor damaged structure should be repaired immediately.

**Mass Movement Hazards**

| Rock/Landslide | High | Earthquake, deforestation, cut and fill of steep slopes | Rapid burial of structures | Grading of road side-cuts to stable slope conditions, re-vegetation, and emplacement of slope stabilization and retaining structures. The retaining structure may consist of gabion or a grouted riprap to avoid embankment failure. Alternatively, benching of the slopes may also be appropriate. Properly designed drainage; direct measure is by sealing cracks and fissures with asphalt or soil cement. |

| Heavy prolonged rainfall | Steep slope and presence of joints and faults | Generating seiche, massive wave within the reservoir |

**Volcanic Hazards**

<p>| Volcanic | Low | Explosive | Collapse of | Immediate washing of accumulated ashes on |</p>
<table>
<thead>
<tr>
<th>Ashfall (2mm size particle)</th>
<th>volcanic eruption of Mt. Kanlaon with prevailing wind blowing to the northwest</th>
<th>roofs, smothering of vegetation, and physical damage to equipments.</th>
<th>roofs. Equipment should be covered when there is an impending ash fall, and the ash should be removed before normal operations.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrologic Hazards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overtopping of Dam due to major flood and landslide within the reservoir</td>
<td>Medium</td>
<td>Heavy prolonged rainfall, Steiche from waves generated from landslide within the reservoir</td>
<td>Flooding of project area A large landslide into the reservoir creates a downstream wave that overtops the dam. This leads to sufficient erosion of the embankment dam, resulting in a breach of the dam</td>
</tr>
<tr>
<td>Surface embankment erosion</td>
<td>Low</td>
<td>Low Surface runoff on embankments</td>
<td>Formation of rill; slope instability</td>
</tr>
<tr>
<td>Gully erosion</td>
<td>Medium</td>
<td>Surface runoff on bare areas</td>
<td>Sedimentation; decrease in impoundment capacity</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the review and evaluation of available geological, geotechnical and geohazard information complemented by field investigation and verification, the following conclusions are hereby presented in relation to the JRMP-II.

1. The sites of the proposed Jalaur High Dam, access road to the proposed Jalaur High Dam and the proposed Jalaur Afterbay Dam are occupied by volcanic, mudstone, siltstone, sandstone,
greywacke, ash tuff and lapilli tuff, fresh to moderately weathered, grey to greenish grey in color, moderate to highly jointed/fractured, inactively faulted, and highly indurated.

2. The proposed Alibunan Catch Dam abutments shall be founded on volcanic, agglomerate, tuff and possibly intrusive dykes that are generally moderately weathered, dark grayish in color, moderately to highly jointed/fractured and hard to very hard in induration. The clasts consist mostly of angular gravel with few cobbles that are mostly volcanic in origin.

3. Most of the hilly, lowland areas that shall be traversed by the High Line Canal, particularly the stretch between Jalaur and Ulian Rivers lie at the footslopes of the Antique Mountain Range. These low areas are mostly underlain by sedimentary rocks belonging to Ulian and Iday Formations of Early to Late Pliocene age. The rocks consist of layered rocks such as siltstone, sandstone, claystone or mudstone and conglomerate. Soil investigation through test pitting classified the soils as mostly fat clays (CH) of high plasticity with occasional silty sand (SM) of low plasticity.

4. There is no active or potentially active faulting at the Project area. The nearest active fault is the West Panay Fault located approximately 11.7 km west of the Project area (proposed Jalaur High Dam). However, several older NW-NE faults cut across the proposed High Dam and Afterbay Dam sites, while, a fault cuts across the proposed Alibunan Catch Dam site. Furthermore, a WNW lineament, secondary to the West Panay Fault runs within the vicinity of the dam sites and correlates with the possible alignment of the historical earthquakes. Inactive faults, lineaments, fractures and joints can be mitigated through engineering intervention.

5. Seismic activity in the Project region is considered moderate; the two largest seismic events occurred in 1948 and 1990 at magnitudes from 8.3 and 7.1, respectively. A Maximum Credible Earthquake (MCE) corresponding to an 8.3 magnitude earthquake generated by the West Panay Fault is considered to evaluate the seismic stability of the JRMP-II structures.

6. Probabilistic estimates of peak ground acceleration (PGA) amplitude at the project site caused by any of the possible earthquake sources in the region is 0.21, 0.4g for medium soil and 0.6g for soft soils (Thenhaus et al, 1994). In the Feasibility Study, a Statistical Analysis of Strong Motion Acceleration (SMA) based on the Iwasaki Method was performed and yielded a PGA value of 0.275g (270 gals).

7. Deterministic estimates of PGA at the site based on an Ms 8.3 MCE generated by the West Panay Fault were in the order of 0.30g for rock, 0.55g for hard soil, 0.45g for medium soil and 0.71 for soft soil (Fukushima and Tanaka, 1990).

8. Results of the dam stability analyses indicated the preferred type of dam remained stable for the different load conditions.

9. Ground rupture produce by the movement of the West Panay Fault is unlikely to affect the structures due to the distance, however, it should not be discounted. Also, surface rupture
from earthquake/s generated by an unmapped and/or hidden fault or any of the lineaments interpreted in the area may affect the project site.

10. The highly jointed nature of the rocks points to a high seepage at the dam site but can be mitigated through application of grouting treatment.

11. The area experiences major floods that could potentially overtop the dams. To prevent overtopping, the dams will be provided with emergency spillways that are designed to convey a 1,000-year flood event. It should be noted that dams would attenuate flooding of the low-lying areas through storage of peak flows.

12. Owing to the natural topography of the catchment area of the proposed Jalaur High Dam where the slope category is between 15-25 percent, the hilly and mountainous the catchment is susceptible to rock/land/debris slide and erosion. The annual sediment yield of Jalaur River at Calinog is estimated at 0.18 MCM. Accelerated sediment yield can potentially reduce the economic life span of the dam.

13. The result of hydraulic analysis of flood wave due to dam break indicates that the flood inundation areas along the Jalaur River under study varies from flood width of 85 m to 2,653 m at Gama Grande Area. The dams will be designed according to seismic and structural parameters. In addition, structural integrity will be monitored during the operation of these facilities.

**RECOMMENDATIONS**

From the foregoing conclusions, it is evident that the seismic and hydrologic hazards are prevalent in the Project area. This had been recognized by the Proponent during the screening evaluation of alternative dam sites. The following tasks are recommended during the construction and operation of the JRMP-II:

1. Site specific ground conditions and PGA should be given particular consideration in the final design of the infrastructures and facilities. Review of previously acquired geotechnical borehole logs in addition to geotechnical evaluations to further refine the dam designs and to address the potential impact of seismic activity to the structures.

2. Additional drill holes positioned upstream from the dam and abutment crests should be considered to get site specific geotechnical properties and be used as input in the dam design.

3. Strict adherence to the design specifications during the construction of the infrastructures and facilities. The proposed structures should also adhere to design guidelines of local (the NSCP) and international design standards (e.g. the USACE, Canadian Dam Association, International) Commission on Large Dams).

4. Establish baseline data for earthquake monitoring before the excavation and reservoir filling.
5. Integrated field inspection should be performed following a major earthquake or flood event. Analysis of structural damage resulting from earthquakes and flooding should be reported and remedial actions, if necessary, should be done at the soonest possible time.

6. Establishment and survey of permanent monuments should be made following a major earthquake on strategic sites to monitor ground movements.

7. Although the Project facilities are in sufficient distance from nearest active fault (West Panay Fault), the Proponent should consider conducting seismic imaging of the dam foundations and immediately in the vicinity of the dam areas to identify major possible structures/discontinuities not evident during the surface mapping. This may also confirm the presence/absence of the NW lineament identified in the tectonic map and possibly in correlation with the historic earthquakes.

8. Continual geologic mapping during the excavation to map unrecognized and undetected and structures during the surface mapping due to limitation of exposure brought about by inaccessibility of the outcrop, and rocks are concealed by vegetation and weathered profile/zone. Modification of engineering design should be considered as the need arises brought about by the changes in the nature and geotechnical properties of lithology as they are uncovered during the excavation.

9. Placement of piezometer to monitor water level changes and ground movement on the dam area and vicinity during the filling of the reservoir where possible movement of unidentified ancient landslide surface may be reactivated and fill the reservoir creating a landslide-induced surge overtopping of the dam and flooding.

10. Employ appropriate engineering solutions on the jointed and weathered nature of the dam foundation.

11. Install appropriate engineering interventions to mitigate landslides and erosion. Pursue Project sustainability efforts such as Watershed Management in partnership with concerned stakeholders.

12. If at some time in the future, the site is redeveloped again such that additional structures are constructed, additional geotechnical investigation should be conducted. The level of investigation will depend upon the type of structure to be built. Additional studies would ensure that potential geohazard conditions are addressed with appropriate mitigation measures.

13. An Engineering, Geological and Geohazard Assessment (EGGA) is performed, and the corresponding report (EGGAR) is prepared. Coupled with additional information required as stated in the MGB-GSS, this report integrates various studies to conform to the format as stipulated in the MGB Memorandum Circular 2000-33.
SUPPLEMENTAL INVESTIGATIONS OF THE
GEOLOGICAL/GEOTECHNICAL INVESTIGATION CUM INTEGRATION
TO THE DETAILED ENGINEERING AND DESIGN (DED)

By: Korea Rural Community Corporation
In JV with Saman Corporation and Dasn Consultant Co., LTD
August 2014

During the conduct of the detailed engineering and design activities, supplemental geological site investigations for the detailed design of dam foundations were conducted such as geological and geophysical exploration as well as on-site Pressure meter tests were conducted to fill in the data gaps obtained from the previous studies.

Summary of the supplemental investigations in the three dams sites, the Jalaur High Dam, After Bay Dam and Alibuna Catch Dam are summarized in Table below:

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Dam location</th>
<th>Jalaur High Dam</th>
<th>Jalaru After Bay Dam</th>
<th>Alibuna Catch Dam</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Geological Mapping</td>
<td></td>
<td>1.0 km²</td>
<td>0.6 km²</td>
<td>0.2 km²</td>
<td></td>
</tr>
<tr>
<td>2. Geophysical Exploration</td>
<td></td>
<td>1600 m</td>
<td>1200 m</td>
<td>-</td>
<td>ERP cancelled</td>
</tr>
<tr>
<td>3. Borehole Drilling</td>
<td></td>
<td>4 holes 160 m</td>
<td>4 holes 160 m</td>
<td>3 holes 90 m</td>
<td>With rock tests</td>
</tr>
<tr>
<td>4. On-Site Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>» Water Pressure Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>» Pressure Meter Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Laboratory Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>cores</td>
</tr>
<tr>
<td>(rock samples)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L.S. – Laboratory Samples

RESULTS OF INVESTIGATION

Geological Mapping

To obtain the detailed surface geological information of each dam site, detailed geological mapping was carries out in each dam sites.

In the High dam area, the andesite bedding dominantly occupies the dam site and is widely outcropped over the area. The bed rock exposed on both of the slopes by erosion are much shattered by the sporadically developed discontinuities such as lineaments and sheared zones, and are moderately weathered with the local weathered surfaces.
On the river bed, the bedrock beneath the thin river deposits appears to be moderately-slightly weathered. The lineament of N28W/74NE direction traverse the dam axis on the left river bed, and is expected to affect the foundation condition of the dam.

In Afterbay dam site, andesite bedding dominates the dam site area, and is heavily shattered by the lineaments of various directions and scales, resulting to the thick highly-weathered zone in the left slope and the collapsed blocks on the right slope, respectively. The lineaments which traverse the dam axis in N84E/80SE~N68E/61E direction on the left bottom and in N57W/47NE direction on the lower right slope, may cause the deterioration on the foundation conditions of the dam along with the conjugated minor lineaments. The depth to the competent foundation are anticipated to be deep on the left slope, and the special consideration requires to be paid on the collapsed block of the right lower slope, taking the recent failure on the upper right slope into considerations.

In the Alibunan Catch dam site, the agglomerate bedding dominates the dam site area, and two lineaments with the respective directions of N85E/66NW and N36W/46SW traverse the dam axis on the river bed. The prominent failure in the left slope of dam axis and on the right slope downstream reveal the instabilities of natural slopes, and require the further observations. The depths of the competent rocks are anticipated to be deep on both abutments, and the bedrock on the river bed is expected to be deteriorated by the lineaments.

Drilling of Boreholes

Jalaur High Dam

Based on the previously drilled holes, the andesite beddings above [CM] grade were encountered at a depth of 3.0-4.0m on the river Bed (HD-1, HD-2) and 3.2-5.0m on the lower depth slope (HD-7, HD-5), respectively. This bedrock of [CM] grade would not provide a competent foundation of the high concrete dam, and, consequently, requires to be intensively reinforced and strengthened.

In general, in fact the Tertiary Lithologic formations provide the lower strength than the ones of the older geologic age (before Mosaic) is widely recognized, and the special attention is required to be paid in determining the foundation condition of the High Dam, taking the above fact and obtained information into consideration.

Jalaur Afterbay Dam

According to the results of the previous boreholes, the [CM] grade bedrock of andesite was encountered at the depths 4.0-4.5m on the riverbed (AD-4, AD-3) and 6.5 on the lower left slope (AD-6), respectively. The lithologic and foundation of this dam are similar to those of the Hugh Dam to be located in the same river basin apart about 2km away downstream.

Alibunan Catch Dam
On the upper left slope (AA-1), the bedrock [CM] grade which can provide a competent foundation for the dam was encountered at the depths of 9.0m beneath the 1.5m thick completely weathered tuffaceous rock [D] grade and 7.5m thick highly-moderately weathered agglomerate [CL] grade. The [CM] grade bedrock of agglomerates appears to be highly brittle with low core recovery of less than 27% of RQD of 0%.

Summary of Laboratory Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Jalaur High Dam</th>
<th>Afterbay Dam</th>
<th>Alibunan Catch Dam</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Specific Gravity</td>
<td>2.84-2.91</td>
<td>2.81-2.95</td>
<td>2.85-2.91</td>
<td></td>
</tr>
<tr>
<td>2. Triaxial Compression Test</td>
<td>c</td>
<td>9.1-15.96 MPa</td>
<td>13.66 MPa</td>
<td>13.41 MPa</td>
</tr>
<tr>
<td></td>
<td>φ</td>
<td>71° - 74°</td>
<td>68°</td>
<td>60°</td>
</tr>
<tr>
<td>3. Uniaxial Compression Test</td>
<td>q_u</td>
<td>31.1 – 36.2 MPa</td>
<td>32-41.61 MPa</td>
<td>25.49 MPa</td>
</tr>
<tr>
<td>4. Tensile Strength</td>
<td>24.75-27.4 MPa</td>
<td>27.53 MPa</td>
<td>27.47 MPa</td>
<td></td>
</tr>
<tr>
<td>5. Elastic Modulus</td>
<td>31.9-37.2 kPa</td>
<td>3.0-5.6 GPa</td>
<td>0.74 GPa</td>
<td></td>
</tr>
<tr>
<td>6. Poisson’s Ratio</td>
<td>0.16</td>
<td>0.11-0.13</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>7. Unit Weight</td>
<td>1.90-1.99 g/cm³</td>
<td>1.91-2.02 g/cm³</td>
<td>1.93-1.95 g/cm³</td>
<td></td>
</tr>
<tr>
<td>8. Elastic Wave Velocity</td>
<td>5008-6150 m/s</td>
<td>4940-5560 m/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INTEGRATION OF INVENTIGATION RESULTS TO DETAILED DESIGN

Design Criteria of the Dams

The design was carried out based on the standard design criteria of USBR and Engineering Manual of Corps of Engineers of USA which has been arranged as the design criteria of the JRMPII.

The result of the geological investigation results was considered into earthquake and dam safety analysis and foundation design. The major items considered into dam design are as follows:

1) Foundation conditions

Andesite bedding predominantly occupies the Jalaur High Dam and Afterbay dam which was discovered that the decomposed layer was found to be at 3.0m to 7.0m range that exist on the fresh bedrock corresponding to a CN Class. Laboratory tests shows the value of the triaxial compression test in the range of 25.0 MPa is comparatively a good rock foundation to endure a 100m high concrete gravity dam body type which requires a proper foundation treatment since it is placed on the fresh rock foundation.

2) Earthquake
The Philippine Archipelago encounters frequent earthquake, hence, the design criteria recommends the USBR earthquake analysis and its corresponding horizontal force, as follows:

- Operation Basis Earthquake (OBE) (25-30 years frequency) : 0.12g
- Design Basis Earthquake (DBE) (100-200 years frequency) : 0.24g
- Maximum Credible Earthquake (MCE) : 0.55g

These forces correspond to the forces that an 8.5 magnitude earthquake would occur at the place distance for 100km, 50-60km and 10 km from the Jalaur High Dam site. This analysis considered the most intensive earthquake with magnitude 8.3 that was recorded on January 24, 1948 which was expected to be caused from Manila-Negros trench developed north-southerly on the northern shore apart more than 100km from Panay Island. The Antique active fault was assumed to pass near the Jalaur High Dam site apart about 10km.

3) Flood

The 1000 years frequency flood was applied to check if the flood would be raised up to the water level over the dam crest as well as whether the discharge would not harm/affect the spillways over bridge structure.

While, a 200 years frequency flood were used to the design flood for spillways both of the Jalaur High Dam and Afterbay Dam. On the other hand, 100 years frequency flood was applied as the design flood for Alibunan Catch dam since it has a comparatively low dam height.

2 years frequency flood was considered as the design flood for the diversion works for all sams since three dams will be concrete gravity type dam which is not much affected by the passing of flood through the work site.

Design Criteria for the Irrigation Structures

For the design irrigation structures, the standard design to be used will be of the National Irrigation Administration design criteria.

Design loading conditions that were considered to derive the minimum shape of the dam body which has a 5m interval safety analysis in vertical height of the dam profile, considering the maximum height of the Jalaur High Dam expected at 109m on the rock foundation:

a) Loading condition No. 1: Unusual Loading Condition - Construction
   - Dam structure completed
   - No headwater or tail water

b) Loading condition No. 2: Usual Condition Condition – Normal Operation
   - Reservoir water elevation at the top of spillway weir crest
   - Minimum tail water
   - Uplift
   - Silt Pressure
c) **Loading condition No.3: Unusual Loading Condition – Normal Operation**
   - Flood water level, when 200 year frequency flood occurred, at both reservoir and tailrace
   - Tail water at flood elevation
   - Tail water pressure
   - Uplift
   - Silt pressure

d) **Loading condition No.4: Extreme Loading Condition – Construction with Operating Basis earthquake (OBE)**
   - Operating Basis Earthquake (0.12g)
   - Horizontal earthquake acceleration in upstream direction
   - No water in the reservoir
   - No water in tailrace

e) **Loading condition No.5: Unusual Loading Condition – Normal Operating with Design Basis Earthquake (DBE)**
   - Design Basis Earthquake (0.24g)
   - Horizontal earthquake acceleration in downstream direction.
   - N.H.W.L in reservoir
   - Uplift at pre-earthquake level
   - Silt pressure

f) **Loading condition No.6: Extreme Loading Condition – Normal Operating**
   - Design Basis Earthquake (0.24g)
   - Horizontal earthquake acceleration in downstream direction.
   - N.H.W.L. at reservoir
   - N.H.W.L at Tailrace
   - Uplift pressure
   - Silt Pressure

g) **Load condition No.7: Extreme Loading Condition – 1000 Year Frequency Flood**
   - M.F.W.L. at Reservoir
   - N.F.W.L. at Tailrace
   - Uplift Pressure
   - Silt Pressure

h) **Loading Condition No.8: Extreme Loading Condition – Maximum Credible Earthquake (MCE)**
   - Same Loading Condition as Loading Condition No. 6
   - Maximum Credible Earthquake (0.55g)

**Spillway**

Non-gated spillway was decided as the Jalaur High dam spillways type at post stage studies. The detailed design adopted the non-gated spillway type for the High Dam and Afterbay Dam considering
of the steep slope of the Jalaur River at 1:3 which makes very fast attach/approach within 2-3 hours to the dam site. It means that in case of gated spillway, there is not enough time to control the discharge.

**Foundation Treatment**

There are two (2) types of foundation treatment, **consolidation** and **curtain grouting** will be applied to the foundation rock of Jalaur High Dam. The foundation rock was designed based on the result of the geological investigation whereas the cohesion ranges between 9.1~15.96MPa and the friction angle vary between 71°-74°.

During the safety analysis, the values that were adopted are 0.65MPa for friction force and 39MPa for allowable foundation strength, respectively.

Even though, it is expected that the foundation rock will be very safe with the above considered values, foundation treatment is still required during the excavation and grouting works of the foundation.

**Dam Instrumentation**

Nine (9) various instruments are provided in the dam body as well as in the foundation. The following apparatus to be installed are as follows:

1) **Thermometer** – will be utilized to monitor the concrete temperature;
2) **Strain Meter,**
3) **Stress Meter** and
4) **Non-Stress Meter** – will be utilized to monitor the concrete stress behaviour;
5) **Pore Pressure Apparatus,**
6) **Uplift Measuring Apparatus** – will be utilized to monitor the water pressure acting at the dam foundation;
7) **Leakage Measuring Apparatus** – will be provided at the gutter of the foundation gallery and will be used to monitor seepage water quantity through the dam body;
8) **Seismo-Accelerograph,**
9) **Plumbness Device** - each dam will be provided at a plumbing device and will be utilized to monitor the behaviour of the dam body when the dam is exposed to seismic effect.

**Slope Protection Method**

Various methods for slope protection are proposed for this project including rip-raping and stone masonry. The contractor shall select the most appropriate slope protection depending on the actual site condition and based on the result of slope stability calculation in specific sections or locations.