

National Centre for Coastal Research
(NCCR)

**Gap Analysis for Preparation of
DPR for Kalpasar Dam**

Final Gap Analysis Report

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
ALARP	As Low as Reasonably Practicable
ALS	Accidental Limit State
BIS	Bureau of Indian Standards
CAPEX	Capital Expenditure
CBIP	Central Board of Irrigation and Power
CFD	Computational Fluid Dynamics
CIfA	Chartered Institute of Archaeologists
CIFRI	Central Inland Fisheries Research Institute
CIRIA	Construction Industry Research and Information Association
CWC	Central Water Commission
DPR	Detailed Project Report
EIA	Environmental Impact Assessments
EPP	Emergency Preparedness Plan
ESIA	Environmental and Social Impact Assessment
EWS	Early Warning System
FAO	Food and Agriculture Organization
FEE	Functional Evaluation Earthquake
FHWA	Federal Highways Administration
FSL	Full Supply Level
GTS	Great Trigonometric Survey
HAT	Highest Astronomical Tide
ICOLD	International Commission on Large Dams
ICOMOS	International Council on Monuments and Sites
IFC	International Finance Corporation
GSDMA	Gujarat State Disaster Management Authority
IITM	Indian Institute of Technology Madras
InSAR	Interferometric Synthetic Aperture Radar
INTACH	Indian National Trust for Art and Cultural Heritage
IPCC	Intergovernmental Panel on Climate Change
LAT	Lowest Astronomical Tide
LiDAR	Light detection and ranging
M&E	Mechanical and Elec
MASL	Meters above sea level
MCE	Maximum Credible Earthquake
MCM	Million Cubic Meters
MDE	Maximum Design Earthquake

MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
NCCR	National Centre for Coastal Research
NCE	No Collapse Earthquake
NIOT	National Institute of Ocean Technology
NOAA	National Oceanic and Atmospheric Administration
Nr	Number
NWL	Normal Water Level
O&M	Operation and Maintenance
OBE	Operating Basis Earthquake
OPEX	Operational Expenditure
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PPP	Public Private Partnership
RAP	Resettlement Action Plan
RCP	Representative concentration pathways
RTE	Reservoir Triggered Earthquake
SCADA	Supervisory control and data acquisition
SDG	Sustainable Development Goals
SEE	Safety Evaluation Earthquake
SLS	Serviceability Limit State
SPS	Safeguard Policy Statements
ToR	Terms of Reference
ULS	Ultimate Limit State
UNESCO	The United Nations Educational, Scientific and Cultural Organization
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USEPA	U.S Environmental Protection Agency
US-FDSC	US Federal Dam Safety Commission
WB	World Bank

Executive Summary

The Consultant, Arup, teamed up with HR Wallingford, UK, have been commissioned by the National Centre for Coastal Research (NCCR) on 14 June 2021 to perform a review of 31 completed studies and seven studies in progress, for the Kalpasar project and undertake a gap analysis.

The Gap Analysis identified 102 High Risk Gaps, 88 Medium Risks Gaps and 7 Low Risks Gaps, split across six Workstreams, namely Dam Engineering; Estuary Water Management and Quality; Geotechnics, Geology and Seismology; Environmental Review, Socio-Economic Impacts and Transport Cost Benefit. It can be noted that, in the process of undertaking the gap analysis, two workstreams that were previously, in the Inception Report, captured under the stream Dam Engineering, have been now kept separately, as they could have significant impacts on the feasibility of the Kalpasar Scheme. These are:

- Socio-Economic Impact
- Transport

The Kalpasar project feasibility has been studied over the past 40 years, considering various aspects, from the technical solution of the dam to the environmental impacts. Data and knowledge have been developed in different levels of detail. The reports and studies in the scope for this Gap Analysis were reviewed for their relevance and quality, within the framework set out in the Inception Report.

After the completion of the Gap Analysis by Arup, it was concluded that there are several overarching themes across the gaps identified across all workstreams Those are summarised below.

- There is lack of clarity on the definition on the Project Aims and Needs, Project Design Brief, Design Limit States and Design Standards
- There is not appeared to be any design integration between the different studies to produce a single coherent design. There is lack of continuity between reports, and there is lack of reference to the project objectives.
- There is lack of clarity of how project decisions thus far have been made and different options evaluated
- Many of the studies provided are out of date and would need updating with most up-to-date available data and currently proposed alignment
- There is no one database or an information model collating and comparing the available data (from carried out surveys) for the existing site and the proposed scheme.
- There is little assessment done on the stakeholders and receptors for the scheme. There is no clarity if any engagement with the potential stakeholders have been made.
- There is little information on how the scheme would impact the wider region and how that affects the region development plans and vision

- There is no up to date analysis of the Costs and Benefits of the Project.

Recommendations and mitigations have been made for addressing the identified gaps. While addressing the gaps will reduce the overall project risk, some of the identified issues, even after mitigation, have the potential to lead to significant cost and time impacts on the project and put the feasibility under review.

1 Introduction

The Consultant, Arup, teamed up with HR Wallingford, UK, have been commissioned by the National Centre for Coastal Research (NCCR) on 14 June 2021 to perform a review of 31 completed studies Kalpasar project and undertake a gap analysis.

According to the contract the following deliverables expected:

- 1 Inception Report
- 2 Draft Review Report that will comprise a review of the completed studies, comments and recommendations for going forward with the design, include actions to be taken for areas of concern as well as further investigations and analysis to be carried out,
- 3 Final Review Report following receipt of a single consolidated set of comments from NCCR.

The NCCR shared the completed studies with Arup and HR Wallingford on 23rd June 2021 and then 3 ongoing studies on 3rd July 2021. A list of the reports received is presented in Appendix 1.

In order to better manage the review process, we have subdivided the tasks into the following components:

- A) Dam Engineering
- B) Estuary Water Management & Quality
- C) Geotechnics/Geology and Seismology
- D) Environmental Review (*amended from Marine & Estuary Environmental review to include terrestrial elements*)

In the process of undertaking the gap analysis two workstreams that were previously, in the Inception Report, captured under the stream A), have been now kept separately, as they would have key impacts on the feasibility of the Kalpasar Scheme. These are:

- E) Socio-Economic Impact
- F) Transport

The details and criteria for the review of each section has been outlined in the Inception Report from July 2021.

This is the Draft Review Report by the Consultant; the report comprises:

- Section 1: Introduction

- Section 2: Reports Reviewed by Each Workstream
- Section 3: General Overview of the Gap Analysis
- Section 4: Workstream A – Dam Engineering
- Section 5: Workstream B - Estuary Water Management & Quality
- Section 6: Workstream C - Geotechnics/Geology and Seismology
- Section 7: Workstream D - Environmental Review
- Section 8: Workstream E - Socio-economic Impact
- Section 9: Workstream F – Transport Cost Benefit Analysis
- Section 10: Conclusion and Recommendations

2 Reports Reviewed by Each Workstream

2.1 A) Dam Engineering

- Pre-feasibility volume 1 & 2
- Techno Economic Feasibility Report Kalpasar
- Primary Dam cross sections finalized 2015
- Pre-Feasibility volume 2
- Design of Dam and Spillway cross section
- Primary Dam cross sections finalized 2015
- Water Availability Studies NIH
- Estimation of PMF, Design Flood and Spillway Capacities IIT
- Design of Dam and Spillway cross section; Six Specific Studies Volumes V and VII
- Six Specific Studies Volume V
- Primary Dam Cross Sections finalised 2015

2.2 B) Estuary Water Management & Quality

- Techno economic feasibility report
- Water quality report
- Water availability study
- A study on positive irrigation impact of Kalpasar reservoir project in Saurashtra region of Saurashtra
- Study of taluka-wise Irrigation planning and Agro-economic impact of Kalpasar project in coastal areas of Saurashtra region
- Irrigation facilities

- Scope of Work for EIA & SIA Studies

2.3 C) Geotechnics/Geology and Seismology

- Final Report on Marine Geo Technical Investigation works for the Gulf of Khambay Development Project (Kalpasar) Government of Gujarat by COMACOE (reported April 2021)
- GEOPHYSICAL SURVEY FOR REVISED DAM CORRIDOR [Component 1 of 4 of the overall project Seabed Engineering Investigations and Model studies for Gulf of Khambhat Development Project] FOR KALPASAR PRABHAG OF NARMADA WATER RESOURCES WATER SUPPLY & KALPASAR DEPARTMENT GOVERNMENT OF GUJARAT PREPARED BY NATIONAL INSTITUTE OF OCEAN TECHNOLOGY CHENNAI January 2013

2.4 D) Marine & Estuary Environmental Review

- Prefeasibility report, Haskoning 1999 Vol 1 and 5, Annex 12.
- Assessment of Baseline Environmental quality and social status of Kalpasar Project, Vol 1 and 2, 2011.
- Hydrodynamic and sediment model studies and related measurements, NIOT, 2018.
- Comprehensive Report on KALPASAR PROJECT Duration of (July-2009 to December-2014), GPCB
- Mangrove Studies, GEC, undated.
- Synopsis of various environmental and socioeconomic studies, GES, 2018
- EIA and SIA studies for Kalpasar Project, NEERI, April 2008. Gov of India, Ministry of Environment and Forests, Meeting Minute 24-Sept-2010.
- Fisheries Report, 2008.
- Assessment of Baseline Environmental quality and social status of Kalpasar Project, Vol 2, 2011.
- Impact of the proposed Kalpasar dam on the ports in the Gulf of Khambhat, Sept 2016.

2.5 E) Socio-economic Impact

- Synopsis of the environmental and socioeconomic aspects of the various studies related to Kalpasar project
- Conceptual and Structure Plan and Preparation of Base Map of Kalpasar Project Area, 2014

- Neeri Scoping Study Report (EIA and SIA), 2008
- Traffic Assessment Study
- Impact of Kalpasar Project on the existing and Proposed Ports
- Fisheries Study
- Present Status of Salt Pans and Assessment of Social, Economic and Environmental Impact of the Kalpasar Reservoir Project
- Socio-Economic Appraisal of the Kalpasar Area (Chapter 2) 2011

2.6 F) Transport

- Traffic Assessment Study

3 General Overview of the Gap Analysis

3.1 Standards and Guides

The Gap analysis was based on National and international Standards, as previously described in the Inception Report. For the complete bibliography used for the analysis refer to Appendix 2.

3.2 Risk based approach for undertaking the gap analysis

In the Inception Report, it was outlined that the gap analysis will be undertaken with a risk-based approach. A matrix was prepared based on the inception report to provide a systematic framework for reviewing the provided reports by the client. The matrix subdivision is explained below.

- Review Component – related workstream
- Sub-component – related to the sub-title for each component in the inception report
- Inception Report section – reference to the inception report section
- Topic – topic examined within a subcomponent of the review
- Assigned to – Information reviewers
- Gap/Issue identified – Description of the gap or issues (if) identified for each topic
- Risk/ Importance (High/ Medium/ Low) – Assigned level of risk associated with the gap/issue identified
- Mitigation/ Recommendation – consideration of possible mitigations
- Reference Documents/ Codes/ standards – reference to relevant international standards and documents
- Kalpasar Report(s) reviewed relevant to this issue – reference to Kalpasar reports reviewed on the topic.

The following definitions have been used throughout the gap analysis:

- High- Risks which could jeopardise the feasibility of the scheme or which have the potential to require a large change to the design with associated impact on design and construction cost.
- Medium- Risks which have not been addressed (or fully addressed) through the studies to date which could be carried out at a later stage or are expected to have a lesser impact on the design and are not likely to jeopardise the scheme's feasibility.
- Low- Risks which have been fully addressed at the study level with only design development required

For conciseness only the key high-risk items have been summarised in the report.

The full the matrix can be found in Appendix 2.

3.3 Overview of Risk Identified

Following the framework set out in the Inception Report and completing the Gap Analysis matrix a number of risks/gaps were identified for each Workstream. The overall number of risks initially directly corresponded to an item stated in the Inception Report. As the review progressed a number of additional gaps/issues were added to the matrix.

Overall, 102 high risk gaps/issues were identified, 88 medium risks and 7 low risk issues were identified. The infographic below shows the split across each workstream.

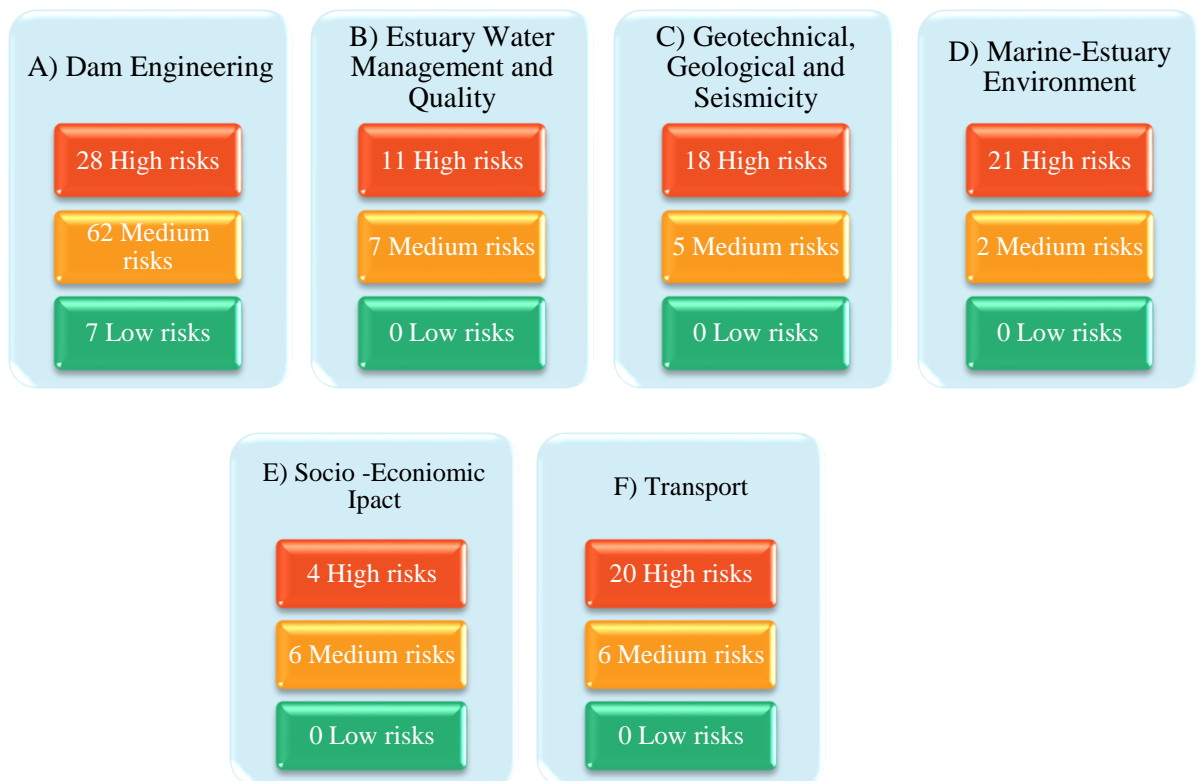


Figure 1. Issues and Gaps Identified Across Workstreams

4 A - Dam Engineering

Following the inception review 28 High Risks, 62 Medium Risks and 7 Low Risk gaps/issues were identified.

4.1 Key High-Risk Gaps

4.1.1 Dam Design Criteria

High Risk Gaps/Issues Identified:

There is **no** document outlining the design aspirations and performance targets for the Kalpasar project.

The dam has not been categorised to appropriate standards based on its hazard potential.

There is no one document outlining the standards to be achieved in terms of reliability, design life or operational capacity, for any element of the proposed dam design, appurtenant structures, or related infrastructure, such as the new road.

No design life or standards were referenced in any of the documents outlining the proposed dam design or related infrastructure, such as the new irrigation canal and the Narmada dam and canal, mechanical and electrical component, roads bridges etc.

As there is a direct relationship between dam safety and its lifespan, the design criteria should be stated in the project reports and briefs for each of the design stages.

Recommendations:

A Design Brief should be prepared stating the project needs and aspirations, as well as standards to be followed. This will aid the setting of Design Criteria, i.e. the Ultimate Limit State Criteria and Serviceability Limit State Criteria (based on recognised standards), for each of the components of the dam. Freeboard and overtopping limits should also be set.

For example, the design life of the dam structure forms part of the ultimate limit state criteria, while expected wind speed and wave overtopping limits before closing the motorway and railway link for parts of the serviceability criteria.

The Design Brief should cover all aspects of the engineering design. The Design Brief should be prepared in accordance with recognised national and international standards. The design Brief is to be issued to all parties undertaking design studies/work.

Residual risk after mitigation:

The Design Brief aim is to provide a framework to which the future design work is conducted. The residual risk is that in meeting all the criteria set out in the Brief, the project becomes unfeasible from technical or cost/benefit perspective.

4.1.2 Water Availability

High Risk Gaps/Issues Identified

A large proportion of the Kalpasar water is supplied by the Narmada River, which already has a large water supply dam supplying an irrigation canal (Sardar Sarovar Dam). Other supply dams are built on the other tributaries, the operating regime of these reservoirs will affect the available freshwater inflows into Kalpasar reservoir.

The water in the tributary rivers flows varies with season and the release of flows from existing reservoirs, the seasonality is not reflected in the water availability estimates. The data presented in the hydrological assessments and demand forecasts is outdated and does not include future projections of climate change, land use/crops and population growth.

No objective for reliability of water supply has been set.

There has not been a long period model simulation of the water inflows, water demands and losses to determine accurately the availability of the water and reliability of supply. A 1 year model has been simulated (NIOT 2018, Dam Impact Model Studies), along with the use of average annual estimates.

Recommendations

The target reliability of water supply should be set. A draft Operations and Maintenance Plan (O&M Plan) should be prepared for the expected performance of the Kalpasar Reservoir. The plan should outline the day-to-day management of the reservoir, including proposed strategy on maintaining the reservoir balance for the available water and demand.

The water balance should be modelled in a long-term catchment-based model (such as 50 to 100 years, reference should be made to “Guidelines for Preparation of Detailed Project Reports of Irrigation and Multipurpose Projects”), so that the reliability of the water supply is proven over a representative time period. The model can then be used to inform the design of the reservoir and operating Plan.

The model should be based on available rainfall-runoff records, sensitivity testing should also be undertaken including for different climate change scenarios. The model should also include forecasts for the water releases from the existing and proposed reservoirs on the tributary rivers, that are adjusted for climate change and predicted changes to the water demands from those reservoirs. The model should be able to capture water losses such as evaporation, spillway releases, salinity flushes and leakage estimates. The irrigation demands from Kalpasar should be modelled to include future forecasts for changes due to climate change, and economic and demographic changes to the region.

Residual risk after mitigation

The results from the updated water balance model may conclude that there is not enough water available for the sustainable long-term utilisation of the dam. There is a high risk that this might affect the cost-benefit analysis and ultimately the feasibility of the project.

4.1.3 Constructability – Closure Construction Sequence

High Risk Gaps/Issues Identified

The construction sequence and the design of the gulf closure section of the dam is only briefly discussed in the Feasibility reports reviewed. Some further modelling of the current velocities is presented in the Dam Impact Model Studies (NIOT, 2018). However, considerations such as sequencing of the work, scour mitigation due to high current velocities in the closure or the inclusion of deep-water salinity flush sluices, are not reflected in the design of the proposed dam cross sections.

The criticality of the closure design cannot be over emphasised. This tidal closure will present issues of an order of magnitude greater than any tidal closures on previous projects around the world and requires very careful planning and design to ensure that scour near the dam is managed and contained at acceptable levels.

The proposed dam cross-sections feature steep slopes and multiple layers at a great underwater depth. The inclusion of the deep flush sluices will require precision of placement to guarantee watertightness and smooth operation, which should be considered in the construction sequence. The proposed dam design should be developed in consideration of the temporary construction cases.

Recommendations

A detailed hydrodynamic model including the different stages of construction should be prepared. That would enable the optimisation of a construction sequence for the proposed dam alignment.

A draft Construction Sequence Plan should be prepared detailing the approach to the construction of the different sections of the dam. A careful consideration should be given for the temporary cases during construction, and constructability considerations should be carried forward in the future stages of the design. It is important to engage potential contractors specialising in marine environment construction to fully integrate the constraints of the site in the design.

Residual risk after mitigation

The Construction Sequence plan should form part of the design process. Early engagement with potential contractors may not be possible. Overlooking constructability issues may lead to substantial project changes late in the project delivery process, leading to unexpected delays and costs.

4.1.4 Constructability – Materials Sourcing and Suitability

High Risk Gaps/Issues Identified

The proposed dam cross sections show a layered dam construction, with a main body of excavated and dredged material, multiple filter layers and rock armour/concrete armour blocks protection. At its widest the dam will reach over 400m at its base. The preliminary estimates for the required quantities of each material were not provided, nor were preliminary options of where those materials might be sourced or how they to are be transported to site and stockpiled.

Of a particular concern is the sourcing of suitable rock, as it has been stated in the reports that suitable rock for the protection of the dam is not available in the vicinity of the of the dam.

For the main part of the dam, it is proposed to use dredged material from the area of the spillway channel and the new Narmada canal. However, no assessment of the suitability of the materials found on the spillway and the canal alignment has been provided.

Recommendations

For a dam of such scale, sourcing materials with the required properties in such large quantities must be considered carefully with respect to source availability and logistics for the material transportation to site. A draft Material Management Strategy should be prepared, considering the quantities, the qualities and the potential strategy for sourcing of the materials. The logistics of transporting and stockpiling materials on site should be considered. A strategy for utilisation or disposal of unsuitable excavated materials should be prepared.

Residual risk after mitigation

The lack of availability or suitability of materials can pose a risk of design changes late in the design process. That can cause significant increases in the cost of the project and possible project delays. Early engagement with potential material sources and developing understanding of the quantities of required and available resources is key for reducing the project risks further.

4.1.5 Cost Benefit Analysis

High Risk Gaps/Issues Identified

Since the early pre-feasibility studies and the techno-economic appraisal of the project there has **not** been an updated cost benefit analysis.

There have been significant changes to the scheme, including changes of the alignment of the dam, the proposed cross sections and the commissioning of the latest stage of the Sardar Sarovar Dam (which affects the water availability). **No** evidence was found in the provided reports of evaluation of multiple options and optimisation of the proposed dam for the reduction of the project overall capital, operational and maintenance costs.

The benefit assessment has only a very high level of indirect impacts assessment for the region, predominantly considering the impacts of improved irrigation for agriculture. Further, socio economic impacts for the region, such as those resulting from improved transport links, were not considered.

Recommendations

Prepare an updated Cost-Benefit analysis for the project. The assessment should be used as tool to re-evaluate the feasibility of the scheme, and in line with the requirements of the DPR, should provide costs and benefits for each individual element of the scheme; for example water supply, transport and tidal surge protection. The document can then be developed into an Optioneering Report and Matrix for selecting and optimising the design of the project. The Cost-Benefit analysis should be kept live and updated with the progression of the design.

Residual risk after mitigation

After re-evaluation of the cost-benefit of the scheme it might be found that the project costs (including risks) are excessive compared to benefits. Alternative options may emerge with a better business case.

4.1.6 Sediment and Salinity Management

High Risk Gaps/Issues Identified

A high percentage of sediment and salinity flushing is assumed. Deep water scour and utilising the spillway are the means of sediment and salinity flushing. In addition, the closure of the estuary will reduce the current velocities in the reservoir, reducing mixing and increasing sedimentation. A hydrodynamic model of the sediment and salinity has been prepared, however only limited cases have been considered. A high volume of flushing through scour and the spillway is required to achieve low salinity in the lake and reduce sedimentation. Only annual average salinity and sediment loads are assumed to be carried through the rivers. However, high salinity has been modelled for the south-west section of the reservoir, which is where the irrigation pumps are proposed to be located. It is not clear whether the salinity will be sufficiently low for crop tolerances and it is not clear what timescales have been considered.

The proposed approach channel for the spillway has a no gradient and therefore the approach velocity to the spillways will be minimal. The lack of velocity in the approach channel will encourage sediment settlement and siltation. The location of the spillway to the side of the dam and away from the mixing zones will also reduce the spillway ability to flush sediment and salt.

Recommendations

The Sediment Model should be updated to reflect seasonality and estuary topography and dynamics. The long term performance of and alternatives to deep-water scour sluices should be considered. The approach velocities and gradients at the spillway should be reviewed to minimise the chance of silting up the approach channels.

The risk of salinity to crops requires study.

Residual Risks

After revising the sediment and salinity to reflect the seasonality and the topography of the estuary, there is a risk that the water may not be of sufficient quality for irrigation, putting the feasibility of the project at risk.

4.1.7 Dam Hazard Categorisation

High Risk Gaps/Issues Identified:

Within the provided studies, the dam is not categorised based on its hazard potential. Multiple dam breach scenarios have been considered in the Dam Impact Assessment study, including the risk of a sea breach at high surge tides.

However, there is no assessment of potential consequences should any of the dam breach scenarios occur. Consequences should include:

- Flood impacts
- Loss of life
- Property, asset and infrastructure damage or loss of operation
- Environmental loss
- Wider economic loss (such as loss of transport corridors or irrigation)

Recommendations:

The Kalpasar dam should be categorised based on its hazard potential, using the approaches described in ICOLD Bulletin 82 and others with particular use of the USACE dam hazard classification.

A dam breach hazard assessment should be prepared. This will serve a number of purposes:

- Inform the selection of design and construction standards, including the safety check flood and seismic design.
- To provide dam breach inundation mapping for development planning
- To determine the consequences of a dam breach and therefore the selection of the reservoir design and safety check floods
- For emergency planning and development of the Emergency Preparedness Plan (EPP)

Residual Risks

A **prescriptive standards based approach** where a dam hazard category is assigned based on criteria such as dam height, stored volume, population at risk downstream of breach and economic consequences. Based on the size of the storage capacity and the height of the dam it is highly likely that the dam will be categorised as high risk.

Alternatively, a **risk-based approach** may be taken where the incremental losses caused by failures in a range of events are considered along with a comparison of flood damages (not resulting from a dam failure). This aims to achieve a risk that is As Low as Reasonably Practicable (ALARP).

This will impact on the design standards that are to be used in the subsequent design stages, the capital cost of the scheme and the operations and maintenance regime.

4.2 Other High Risks Gaps Identified

4.2.1 Hydrology and Hydraulic Modelling

The Probable Maximum Flood (PMF) has been estimated, but no other flood events are considered. A range of flood events combined with tidal variation should be considered in the design. The PMF assumes no contribution from Narmada - it is not clear how the contribution from the Narmada will be managed during floods.

The latest hydrological study is dated 2011. The Probable Maximum Precipitation (PMP) estimates do not appear significantly greater than the maximum observed event. There has been little or no evidence presented of model calibration or event testing. The hydrological assessment assumes that the existing dams regulate the catchment contribution to the estuary; we need to ensure that there is supporting legislation in place to ensure this is the current practice.

As there have been several big events in the region in the last decade it is recommended that the hydrological study is updated to include recent data; it is recommended in particular that the use of the radar network is explored to bolster the rainfall analysis which in the previous study was limited to a small number of rainfall gauges. For Further guidelines and recommendations refer to inception report.

A joint probability analysis should be performed considering combinations of fluvial and coastal storms.

4.2.2 Climate Change Impact

Climate change is already leading to changes in the intensity and frequency of events which can impact dam infrastructure, these impacts are anticipated to continue increasing and intensifying in future climate conditions. A comprehensive report on the potential climate change impacts was not found in the available studies. Understanding the long-term effect of climate change is key to ensuring that dam and the related infrastructure is resilient and sustainable. For key considerations please refer to the inception report.

The whole life cost of the dam should be assessed considering the need for future climate change adaptations, either providing additional capacity where appropriate or allowing for ease of future modification with the decisions based on lowest whole life cost.

4.2.3 Proposed Dam Cross Section

The detailed design of the cross section of the dam body is complicated and it is not clear how it could be constructed in the prevailing depths and tidal conditions. The cross section, which will vary along the length of the dam with varying depth, exposure and geotechnical conditions, will need further optimisation but in addition this optimisation will need to focus on constructability as described in Sections 4.1.1, 4.1.3, and 4.1.4.

There was no design report accompanying the cross sections, and therefore there was a lack of clarity on how the sections were developed. The following key considerations need to be outlined and consistent throughout all documentation and reporting, and were not found in the available reports:

- Standard design units and reference datum
- Design life for dam and for replaceable elements (see section **Error! Reference source not found.**)
- Geometry

- Stability analysis
- Seepage analysis
- Topographical and bathymetric data
- Metocean data for various return periods
 - Significant wave height and period (reservoir-side and gulf-side)
 - Current data (including river outflow effects, variation with depth)
 - Wind speed & direction (monthly, seasonally, annually)
 - Temperature
- Tidal data – Obtained from ESSO - Indian National Centre for Ocean Information Services or similar recognised body
 - Highest astronomical tide (HAT)
 - Mean high water springs (MHWS)
 - Mean high water neaps (MHWN)
 - Mean sea level (MSL)
 - Mean low water neaps (MLWN)
 - Mean low water springs (MLWS)
 - Lowest astronomical tide (LAT)
- Water levels
 - Highest combined tide + storm surge level
 - Lowest combined tide and negative surge level
 - Sea-level rise allowance due to global warming
 - Reservoir water level range including Normal Water Level (NWL)/Full Supply Level (FSL), Peak Stillwater level (design and safety check), minimum level
 - Gauge data for upstream catchments for upstream fluvial analysis
 - Discharge rates for dams in the upper catchments
- Design return periods need to be specified
- The appropriate levels of risk should ultimately be decided by a combination of:
 - Industry standards (including those listed above) and national regulations
 - Cost-benefit analysis to determine as-low-as-reasonably-practicable outcomes (ALARP)
 - Acceptable degree of damage – balance of CAPEX with OPEX (including maintenance/repair and impact of downtime).
 - What funding agencies or insurance companies will accept
- Materials
 - Proposed material properties
 - Source of material

4.2.4 Geometry

It has not been demonstrated clearly how the proposed dam geometry meets all design considerations and project needs. Refer to Section 4.1.1 for the need of

preparing a Design Brief. The design geometry should balance the different design objectives and requirements set out in the Design Brief.

The key parameters are:

- Crest width
- Crest height
- Road/rail vertical and horizontal alignments (see sections 4.2.11 and 0)
- Downstream (Dredged material) slope
- Upstream (Rock core) slope
- Rock/block armour layer thickness
- Rock/block armour diameter
- Settlement Allowance
- Freeboard allowance

The required crest width and width of the various berms will follow from stability analysis and ensuring any shallow failures do not jeopardise the safety of the dam but also operational requirements such as maintenance access. The width of the crest, berms and therefore overall dam footprint is expected to be heavily influenced by the width of the road and rail corridors. The width of the dam will also influence the seepage analysis where a narrower dam will be more prone to seepage and therefore the resulting risk of internal erosion and saline intrusion. This variation in seepage path length will also influence the appropriate choice of material with lower permeability material and more significant seepage cut-offs for narrower (and/or higher) dams.

The height of the dam will need to be sufficient to manage:

- The required reservoir water storage volume needed to meet the demand including any loss due to saline stratification and sediment dead storage
- The modelled design and safety check flood rise, this is therefore related to the spillway design, gate operating philosophy and flood modelling
- The freeboard allowance required to prevent reservoir wave overtopping
- Operation requirements for the road and railway such as remaining operational (spray/overtopping) in specified return period events
- Reservoir impoundment and reservoir rim flood risk
- The tidal range and storm surge
- The freeboard allowance required to limit wave overtopping from the sea
- Allow for settlement of the dam whilst still maintaining all of the above

The height of the dam also strongly influences the dam hazard categorisation, with higher dams generally resulting in greater consequences of failure and therefore posing a higher hazard.

4.2.5 Loading

In the provided reporting it was **not** clear Design return periods for the dam and structures need to be specified for ALS, ULS and SLS design scenarios. Refer to Inception report for examples of standards/code guidance that can be used to define the loading limit states. Those should be defined in the Design Basis/ Brief Report.

Ship impact

All safety critical structures such as spillways, locks and sluices should be designed for dynamic forces arising from ship impact and impact of large debris. An assessment should be made of the likely type and size of ship and likely debris as well as the design impact velocity and deflection.

Methods for assessing the loading due to ship impact are given in EN 1991-1-7, Accidental Actions, or AASHTO Bridge Design Specifications.

4.2.6 Stability Analysis

Although the stability of the completed dam has been assessed, there has been no assessment of the dam stability during the construction process, As well as the geotechnical stability of the dam and its foundations, there are many other factors to be considered, such as wave action, seismic events, floods, and impacts of climate change. Risks of damage are also affected by the duration of the construction process and an understanding of the proposed construction method should be an integral part of the design process. Refer to Section 4.1.3 and Section 6 for recommendations.

4.2.7 Rock armour design

The downstream (seaward) slope, with a vertical height of up to about 44m, is planned to be protected by a layer of concrete Xbloc armour units of 8t to 48t weight, on a base layer of rock of 1.3 to 2.4m thickness. The unit weight of the armour units appears to be appropriate in relation to possible design wave heights although smaller armour units could be used in those parts of the dam in shallower water with depth-limited waves. The presence of berms at several levels on the armoured slope will affect the amount of overtopping.

The design of the protection of the upstream face of the dam also requires consideration.

No information has been seen regarding the selection of the type of armour unit, which will be affected by construction conditions and overall cost. The method of construction is not clear, and construction of relatively thin base layers in conditions exposed to waves and variations in tide height, in depths of more than 20m, might not be practicable with the accuracy implied by the complex cross-section.

4.2.8 Scour protection

The seabed and the dam will be vulnerable to scour damage from tidal flows as construction progresses along the length of the dam and particularly in those areas

affected by the closure. Scour protection along the length of the dam and upstream and downstream of the closure section and the spillway will be required in advance of the main dam construction. Some of this will have a permanent function while other parts may become buried as construction proceeds. Refer to Section 4.1.3 for recommendations and the Inception report for relevant guidance and standards.

4.2.9 Freeboard and Overtopping

It is not clear how the freeboard allowance has been determined and incorporated in the dam design crest level. Only seaside wave run up has been considered and not reservoir wave run-up. Given the openness of the reservoir and the length of the wind fetch, significant waves can develop in the reservoir side.

Overtopping of the dam both from the sea and reservoir will need to be assessed to ensure the design minimises the risk of damage to the dam. It is not clear whether settlement has been considered.

The rate of safe overtopping tolerable to a dam will usually be extremely limited and based on the duration of the overtopping flow and velocity of the flow on the downstream face. In addition, limits should be placed on overtopping for the safety of operation of the highway and rail corridors as well as safe access of inspection, maintenance and emergency response. This should be based on limiting overtopping flows or spray to those safe for pedestrians and vehicles. The extreme floods under which the road and railway are closed to traffic should be agreed with the client and respective authorities.

An analysis of short-term settlement should be made to inform the phasing of the works and management of differential settlement between structures and earthworks. Long-term settlement monitoring should be carried out to ensure the minimum required dam crest level and height of any seepage cut-off is maintained throughout the design life of the dam.

An additional consideration for embankment dams is that the peak still water level remains below any impermeable core or barrier within the dam with an allowance made for settlement and desiccation.

4.2.10 Dam Access for inspection and maintenance

There are currently no proposals for surveillance operation and maintenance of the dam structures. No access route designs have been provided.

Access to the dam site is important both for construction and for ongoing surveillance and maintenance of the dam. Access roads for inspection and maintenance need to be accessible in a reservoir emergency and so need a good standard of protection from flooding and from other hazards such as rockfalls and landslides. The roads need designing with sufficient width and turning space for the largest vehicles envisaged as being needed during inspection, operation, maintenance, or emergency response. This could take the form of access of the main highway with turning areas to access dam infrastructure. Vehicle bridges are therefore typically required over obstructions and structures such as the spillway.

4.2.11 Highway and Railway Design

No details on the proposed road and railway alignment were provided. The design of the transport corridors would impact on the dam design criteria, constructability and material availability. Proposed criteria for operation, such as wind velocity and flood levels at which the road and the railway must remain operational should be included in the Operations and Maintenance Plan. The future stages of the design should also consider details of the bridges and the connecting infrastructure.

4.2.12 Mechanical equipment

No design life or standards are referenced within the feasibility or the proposed M&E structures components, such as spillway gates, draw off pipes or pumps for lifting irrigation of water. There is a direct relationship between dam safety and its life-span, i.e. if the dam is unsafe its life-span has expired.

A design life for the M&E equipment is to be agreed on project leadership scale and requirements included in the brief for the subsequent design phases of the project. Where mechanical and electrical components with a shorter design life are used the design must consider how they may be safely refurbished or replaced. Where a range of options for equipment with differing design life exists the whole life cycle cost should be assessed including differing maintenance and replacement/refurbishment intervals. The design life for replaceable M&E components should be at least 25years.

The selection of appropriate options (e.g. pumping vs sluices) and appropriate gate choices should be reviewed in an option selection exercise. Where either gates or pumping is utilised to remove the saline water at lower levels, careful consideration needs to be given to sedimentation and the impacts this will have upon the operation and longevity of the equipment.

The reservoir water level and inflow will require monitoring to inform gate and sluice operation and flood warnings and emergency response. Such monitoring will also inform water resource planning. Similarly, sea levels will need to be monitored to inform gate and sluice operation and to provide warning in case of emergency.

All gate options will require instrumentation to be integrated into a SCADA system for control and health and condition monitoring. Due to the criticality of the system, the security of it will need to be considered. As well as security of access and control the reliability of the system should be considered. Redundancy of power and operation of safety critical systems such as spillway gates will be required. Control systems will need to link to early warning and flood warning systems.

4.2.13 Instrumentation Plan

The operation and regulation of the water levels of Kalpasar Reservoir is a complex system including gates on the new Narmada Canal and barrage, spillway gates, scour sluices, irrigation pumps, etc. All management operation options will require an integrated approach of instrumentation and monitoring.

At present no Operation and Management Plan has been provided, as discussed in Section 4.1.2, and no instrumentation and monitoring plan has been provided.

All instrumentation should be integrated into a SCADA system for control and health and condition monitoring. Due to the criticality of the system, the security of it will need to be considered. As well as security of access and control the reliability of the system should be considered. Redundancy of power and operation of safety critical systems such as spillway gates will be required. Control systems will need to link to early warning and flood warning systems.

4.2.14 Emergency Preparedness Plan (EPP)

No outline EPP has been provided. This should be prepared and discussed with stakeholders before construction begins. No stakeholders have been identified. Refer to Section 4.1.7 for recommendation and Inception Report for typical contents of an EPP.

4.2.15 Narmada Canal

No proposed alignment or design details are provided for the Narmada Canal and the Barrage. There are limited details on the flows the canal is expected to carry, and they are critical for the water availability for the Kalpasar dam. The design should be developed further in subsequent design stages and its management included in the O&M Plan.

5 B - Estuary water management and quality

5.1 Key High-Risk Gaps

5.1.1 Integrated approach for delivery information

Issue Description

Multiple reports were made available for review, however, there was no integrated and consistent method of presentation for the information. The studies are often presented in a standalone format and there is a lack of continuity and little cross-referencing between previous findings and reports.

Three different hydraulic models for the project were made available for this gap analysis, with different domains and different purposes. There is no over-arching model or reporting structure for the models.

There is no georeferenced or time reference database for the information available. Key stakeholders and receptors were not identified, such as Nirma Chemical plant built within the proposed reservoir basin.

Recommendations

Prepare an integrated Desk Study Report on conducted studies and models; compare findings to project aims. Identify key stakeholders and receptors both

upstream, and downstream of Kalpasar, to enable evaluation of the project impact on the estuary, such as impacts on flooding and water quality.

Prepare a georeferenced and time referenced database of the available studies and findings to enable better understanding of the localised and catchment-wide influences and impacts on the estuary and water quality.

Residual risk after mitigation:

An overarching study on the estuary will enable early engagement and design influence to mitigate the risks posed to and by the project. It can identify the need for implementing mitigations, such as protection from floods. There is a risk of increased design and construction time, and increased costs in implementing any mitigations.

5.1.2 Water availability – seasonality

Issue Description:

There is no recent information on water availability in the catchment or analysis that considers seasonality of the inflow.

One specific report relating to the techno-economic feasibility states that the calculations to deduct the water availability in the catchment area are using the monthly inflow series for the period from 1901 to 2006 which is not recent enough to estimate the current water availability.

Another study referenced in this report has refined the assessment of the water availability which was done by the Central Designs Organisation (C.D.O.) in 2009 considering a greater number of rain gauge stations, establishing modified rainfall runoff relationship for each of the river basins, future planning in the basin up to 2025 and demand assessment in the study area.

Other specific issues relating to water availability have been described in section 4.1.2. of this report. Again, more recent data is required as well as water availability forecasts based on the latest climate change projections.

Recommendations

Understanding the current and future water availability is crucial to the feasibility of this project. The mitigation actions listed out in Section 4.1.2. are recommended for action.

We also propose to obtain recent monthly rainfall data and revise water availability projections taking into account the latest climate change predictions.

Residual risk after mitigation

The results from the updated water balance model may conclude that there is not enough water available for the sustainable long-term utilisation of the dam. There is a high risk that this might affect the cost-benefit analysis and ultimately the feasibility of the project.

5.1.3 Water demand

Issue Description

The water demand highlighted in the studies relates to drinking water consumption, crop irrigation use and industrial use. The main concerns reside in the outdated, or lack of data reported in the studies. These are broken down below by usage.

Drinking water: Data from the reports [1 – Prefeasibility vol.1&3], which were written in 1998, is outdated and include future projections of population growth (2010, 2035 and 2060, assuming the dam would be in service by 2010). It is necessary to update the projected population growth and water demand forecasts as these are likely to have changed over time.

Irrigation use: Data from the reports is outdated and does not include future projections of land use/crops. Climate change forecasts are not taken into account either.

In Report 22 [- Study of taluka-wise Irrigation planning and Agro-economic impact of Kalpasar project.], the land use pattern used to assess water needs for irrigation purposes dates back to 2003-4. The land use and crop patterns are likely to have changed since this study was carried out. More recent data is needed to understand current and future irrigation water consumption.

Industrial use: No information available in the reports provided about the current and future water demand for industrial and other commercial purposes in the region.

Recommendations

Drinking water: Obtain the latest population information expected to have access to water for drinking purposes, as well as and robust population growth figures for the next 30-50 years.

Irrigation use: The latest available data on the crop type, surface area of each crop type, associated water usage and future forecasts of agricultural land use in the next 30-50 years should be obtained.

Industrial use: We propose the collation of the latest information available on the industrial and other commercial current water demands and future forecasts (30-50 years horizon).

Residual risk after mitigation

The results from the updated water balance model may conclude that there is not enough water available for the sustainable long-term utilisation of the dam. There is a high risk that this might affect the cost-benefit analysis and ultimately the feasibility of the project.

5.1.4 Identification of flood receptors and consequences

Issue description

There has been no assessment on the possible flood receptors and flood consequences in the reservoir basin area (low lying reclaimed lands), low-lying

reaches of the rivers discharging directly in the basin, or the downstream coastal areas. In the dam impact assessment model, the domain extents have been limited and do not include a representation of those reaches.

Only dam breach scenarios and resulting extreme tides scenarios have been assessed, without mapping the flood extents in the estuary. Fluvial flooding of different return periods, seasonality and combined probability events have not been assessed to determine the pre and post construction risk of flooding in the estuary.

There has been no assessment of potential environmental impacts in and around the reservoir and the estuary, as a result of changes to the risk of flooding. For example, there has been no assessment of potential sources of pollution, such as Nirma Point chemical plant; changes to the water levels upstream of the dam could impact on water levels in tributaries, potentially increasing them. Without tidal flushing, pollutants released in flood events would impact on the reservoir water quality.

Recommendations

Multiple flood scenarios with a range of return probabilities from different sources (fluvial, tidal, tsunami, storm surges, etc) should be simulated and mapped for both pre-dam and post-dam cases to establish the overall impacts on flood risk in the estuary from the project. Assessment should be made of consequences of all flood scenarios to establish the associated flood receptors and consequences. Carry out an assessment on the risk for economic and environmental damages, such as triggering water pollution incidents or closure of vital local infrastructure.

Residual risk after mitigation

The results of the consequence modelling will inform the dam hazard classification, which may have design, maintenance and cost implications. There may also be a need for mitigation against flood risks in the downstream area particularly, but also in the tributaries feeding the reservoir; this would also have cost implications.

5.1.5 Extreme tidal range impacts

Issue description

The most recent analysis on extreme tidal range identifies a 1.8m increase downstream with the dam in place. This is a major increase in levels which could require significant mitigation to prevent additional flood risk to receptors downstream of the dam.

Noting the processes that generate the macro tide range, there is low confidence that the model domain can encapsulate the whole of the effect of the dam. It may also lead to overprediction of the magnitude of effect on tide at the barrage line, creating high increases in tide levels within the estuary downstream of the dam.

Recommendations

Sensitivity testing of a larger model domains should be carried out to check for the effects on tidal level changes. The model domain size should be extended to a point where further widening does not lead to significant water level changes in the

predicted tidal ranges. The cyclone model area used elsewhere is an example of a larger model domain.

Residual risk after mitigation

The sensitivity testing should confirm if the tidal level increases are real or a factor of the model domain. If the levels are real, significant mitigation will be required and cost will be incurred. Larger model domains may also identify previously unknown affects further downstream.

5.1.6 Pollution risks, sources and receptors

Issue Description:

The water quality data provided in the reports is not recent enough to determine the current status of the water quality in the estuary. Also, obtaining, seasonal analysis of water quality trends would be beneficial to determine the variation in water quality during the year.

In Report 8 [- Water quality report] the water quality data is displayed as an annual average over 5 years (July 2009 – December 2014). The data is outdated to fully assess the most recent status of the water quality in the catchment.

Salinity related considerations are set out in section 4.1.2.

Possible mitigation:

Obtaining water quality data at a finer resolution (e.g. monthly) would allow to monitor the trends of the parameters during different seasons. The collation and analysis of more recent water quality data in the estuary is recommended including turbidity, BOD, COD, TSS, Nitrogen, Phosphorus and heavy metals.

We recommend the production of a Pollution Prevention and Management Strategy which tackles both the diffuse pollution and point source pollution issues and proposes appropriate measures to prevent and control discharges into the rivers feeding into the estuary.

Residual risk after mitigation:

There is a medium risk that the water quality of the estuary will be poor which could result in environmental and human health issues.

5.2 Remaining high risk gaps

5.2.1 Strategy for management/adaptation for protection of the dam and surrounding area.

There is no return period attached to the extreme water level study based on cyclones. It targets a probable maximum storm surge based on the historical record. This is then added to the highest astronomical tide level and modelling of wind waves. The validation of the model or tide alone or surges is vague. The best is that

the predicted surge was 2.2 m compared to an observation of 2 m. A 10% difference is quite large in this context.

5.2.2 Salinity

Impact of salinity on crops is not fully considered, only seems to consider a short time period rather than long-term effects. Study required into long-term risk of salinity to crops. Refer to Section 4.1.6.

6 C – Geotechnics and Seismicity

6.1 Key High-Risk Gaps

6.1.1 Integrated Approach for Delivery of Information

Issue Description

Whilst various investigations have taken place and have been made available for this gap analysis, these have not been reviewed together to provide a combined ground model. There is no georeferenced model that recognises the transient nature of seabed levels. Changes through time, i.e. between studies, have not been investigated.

Recommendations

Prepare an overarching Desk Study bringing together the already available information for the existing ground conditions, from previous geophysical studies of the site. The Desk Study is to identify the ground issues and risks. The report is also to identify any gaps of the knowledge. The desk study report is to compare findings to project aims.

Along with the Desk Study, prepare a georeferenced (using common zones) and time-referenced ground model, to investigate the movement of the seabed levels and the fault lines that run across the proposed location of the dam.

Residual risk after mitigation

The geotechnical and seismic findings are likely to have a significant impact on the design geometry and cross sections of the dam. Capturing those constraints early will reduce the residual risk to the project to low. However, designs dealing with these issues could increase costs and impact the benefit cost of the project.

6.1.2 Design Standards

Issue Description

Local design standards need to be enhanced based on best international practice. It is important for a project of such scale to meet best practice internationally.

Recommendations

Appropriate local and international design standards related to seismic design need to be confirmed in the Design Basis. Refer to Section 4.1.1, and the Inception Report for relevant design standards. Further work will need to be undertaken to develop the applicable codes based on the agreed classification of the structure.

Residual risk after mitigation

The Design Brief aim is to provide a framework to which the future design work is conducted. There is a low residual risk that in meeting all the criteria set out in the Brief, the project becomes unfeasible from technical or cost/benefit perspective.

6.1.3 Dynamic Seabed

Issue Description

From the surveys provided it is clear that the bed of the inner and outer gulf is a very active environment with constantly changing levels. Differences of up to 30m in levels appear to have developed over the few years between successive bathymetry and borehole location surveys. This means that geotechnical investigation of the soils within 30m of mean sea level provides only a ‘snapshot in time’.

Sand ridge and bar migration will result in variable bed level, density, and strength development in the shallow foundation soils until the dam construction is complete. The proposed earthfill dam will have large volume of material below MSL. The shifting nature of the seafloor will add complexity in the calculation of dam material volumes and reduce their certainty. Consequently, dam construction cost and programme are going to unpredictable

Recommendations

A study of seafloor morphology and scour should be undertaken to understand how the seabed changes with time. This may include on site monitoring work over a period, to develop an understanding of the rate of change and typical patterns.

Residual risk after mitigation

With improved understanding of the material migration and scour, there will be residual uncertainty about the exact floor state at the time of construction. As the construction commences, the scour patterns will change with the estuary closure narrowing.

6.1.4 Site -specific study on Seismic Hazards

Issue Description

No site-specific seismic hazard assessment has been carried out to define the design criteria. It is expected that this should be a site specific probabilistic seismic hazard assessment (PSHA). This should define the Safety Evaluation Earthquake (SEE), the Operating Basis Earthquake (OBE) and an earthquake to be considered during the construction phase (CLE). The potential of Reservoir Triggered Earthquakes (RTE) should also be considered.

Recommendations

A site-specific seismic hazard assessment should be prepared. This seismic hazard study must be consistent with the performance requirements set out in the Design Brief and in accordance with the design standards for the relevant hazard classification for the dam.

Residual risk after mitigation

The updated seismic study would influence the design of the dam.

6.1.5 Liquefaction

Issue Description

The current liquefaction assessment is not based on a site-specific seismic risk assessment. There are thick deposits of silty sand at the base of the estuary, and dredged material from the estuary base is proposed to make up the majority of the dam embankment. Silty sand materials are highly susceptible to liquefaction in a saturated environment.

Recommendations

The liquefaction assessment should be updated once the site-specific seismic hazard assessment has been completed, for SSE, OBE, CLE and RTE.

Residual risk after mitigation

The liquefaction assessment will impact on dam geometry and cross sections as well as the material selection. There is a medium residual risk that the engineering solution to mitigate the liquefaction risk are going to add cost and complexity to the design and construction of the dam.

6.1.6 Tsunami

Issue description

The tsunami hazard assessment report by NGRI does not consider other tsunami sources (volcanoes, landslides, meteorological etc.). Furthermore, based on an initial review, the proposed model does not appear to match observed events such as the 1945 Makran tsunami which had a maximum water height of 17m at Pasni, Pakistan. Additionally, the NOAA tsunami database indicates 2m water height in Mumbai for the 1945 event, which is much higher than the values calculated for Scenario 1 in the NGRI report.

Recommendations

The tsunami hazard assessment should be updated to include a range of possible sources. The model should be verified and calibrated against previous known events in the region.

Residual risk after mitigation

Once the tsunami hazard is understood, the required design modifications to prevent serious damage to the dam could increase costs and significantly decrease the benefit cost ratio.

6.1.7 Unknown Faulting

Issue description

It is not clear if all regional and local faults, and the evidence of their seismic activity, have been identified. Existing records of faults may not be sufficient to identify all faults, with some faults not yet identified.

Recommendations

A regional and local fault mapping exercise should be undertaken. This should feed into the site specific seismic hazard assessment, collating evidence for fault activity. New geophysical studies should examine whether there are any unknown faults under the proposed alignment.

Residual risk after mitigation

New faults discovered by the fault mapping and new information about existing faults with relevance to the dam will have an impact on the design which will need to mitigate against the potential hazards. This has the potential to increase costs and reduce the benefit cost ratio.

6.2 Remaining High Risk Gaps

6.2.1 COMACOE zones and data

The COMACOE Geo-Technical Investigation Report (Reported April 2021) although called final appears to require further review. For example, the report is divided into 7 Zones but appears to be missing all of the borehole and in-situ test data (Appendix B and C have information from a different zone) from Zone 1. The report should be finalised, and all data included.

6.2.2 Variance in ground investigation zones

The report by COMACOE is divided into 7 Zones, however the IITM assessment of the data reduces this to 6 Zones. A consistent referencing system needs to be established to avoid confusion.

6.2.3 Rim stability/Landslides

The potential for mass movement hazard needs to be assessed in relation to the reservoir basin. Risks of mass movements in the reservoir rim area must be evaluated and mitigation measures may be needed. The stability and structural integrity of the reservoir rim upstream of the structure must be evaluated for all potential loading conditions whether hydrologic, earthquake, or other hazards, man-made or natural. Reservoir rim instability may lead to poor water quality, blockage of channels and structures and waves which may threaten reservoir users and the

dam structure. Risks of mass movements in the reservoir rim area must be evaluated and mitigation measures may be needed.

6.2.4 Basin leakage

Basin leakage during impoundment occurs when infiltration of reservoir water is occurring through the surrounding and underlying soils, which is problematic if seepage occurs beneath the dam retention structures and can cause other erosional issues for the reservoir area. The permeability, hydraulic conductivity, and porosity of the soils supporting the reservoir volume should be evaluated. Erosion potential and corrosivity of the foundation soils should be evaluated.

6.2.5 A study of alternative construction options

Alternative construction methods (other than mass filling) for part of the structure should be considered. For example the use of caissons of known geometry that can be floated out and ballasted into position on a seafloor prepared by suction dredger or similar. Such options could significantly reduce the quantity of mass fill required.

6.2.6 Seismic performance criteria

No seismic performance criteria have been defined relating to the operational and safety requirements of the Kalpasar dam and the linear infrastructure (rail, highway, communication, etc) that it will carry. The seismic security and the operational resilience of the various installations require evaluation and stakeholder agreement. It should be noted that due to the nature of the project, there are no current Indian or international codes which adequately define these requirements. The performance criteria should be both qualitative and quantitative (e.g. acceptable settlement and/or displacement limits). This should define performance requirements for both operational (serviceability) and safety (ultimate) requirements which must consider the multi-functional aspects of the project. See Tables 3-1 & 3-2 in the Inception report for some suggested high level seismic criteria.

6.2.7 Site response analyses

No site-specific site response analyses have been carried out. These studies model the influence of the near-surface layers on earthquake ground motions. The near-surface layers act as a filter that amplify/de-amplify the seismic waves coming from the earthquake source. The site response studies should account for the variation in geology along the length of the dam, the impact of scour, the presence of mobile soils and the impact of the dam on the in-situ stresses. A series of site response analyses should be carried out along the length of the dam at regular intervals. Intervals should be selected based on the variation of the underlying geology.

7 D –Environmental Review

7.1 Introduction

This part of the gap analysis has considered the treatment of marine and estuary environment issues and wider terrestrial biodiversity issues in the documents provided, in the context of best practice Environmental and Social Impact Assessment (ESIA) processes. The review has focussed on a gap analysis of risks associated with the main environmental assessment topic areas, and the interaction of these risks with the overall project business case.

The gap analysis has therefore assessed whether the main environmental risks from the project are being appropriately considered and managed. The analysis also considers whether the environmental impact studies conducted to date will provide the required evidence and quality of assessment in accordance with national and international standards and good practice.

7.2 Context for the review of marine, estuary and wider environmental issues

The development and operation of the Kalpasar barrage has the potential for significant impacts on the local estuarine environment and beyond. To comply with national and international practice in ESIA, it is essential therefore that all major environmental impacts and costs are scoped and assessed and that alternative options that may satisfy the project aims are fully considered.

The review and gap analysis has therefore considered whether the existing assessment materials encompass the major risks posed by an estuarine barrage. Examples of the likely main issues can be found in the HR Wallingford publication ‘Guidelines for the Assessment and Planning of Estuarine Barrages’ (Burt and Rees, 2001). That said, the issues and assessment of marine and estuary impacts for the Kalpasar project also need to be grounded in the local and regional environmental conditions at the site. These include:

- Effects on river and estuary hydrodynamics, morphology and flood risk;
- Biodiversity (including terrestrial habitats) effects from the footprint of the barrage structures and associated infrastructure, the water impoundment and water level, quality changes inside and outside the barrage and potential dredging areas required for dam material fill;
- Climate implications from resource usage and energy consumption during construction and operation, as well as the potential to be affected by, and/or act in combination with, climatic changes associated with climate change (e.g. extreme weather events or increased tidal ranges);
- Direct and indirect displacement of people with estuary-based livelihoods within and outside the barrage area (see also Workstream E);

- The development of practical and effective measures to mitigate and compensate for adverse physical, natural and human effects.

In addition, this component of the gap analysis has considered the potential acceptability of the assessment information (with regard to marine and estuary effects) and the residual risks with respect to international institutions such as the Asian Development Bank (ADB). This has been done by reference to the ADB's Safeguard Policy Statement (SPS).

The SPS aims to promote sustainability of project outcomes by protecting the environment and people from a project's potential adverse impacts by avoiding adverse impacts of projects on the environment and affected people, where possible; minimising, mitigating, and/or compensating for adverse project impacts on the environment and affected people when avoidance is not possible.

7.3 Key High-Risk Gaps

7.3.1 Scoping and integration of approach for delivery of environmental information

Issue Description:

The reports prepared to date demonstrate evidence of the technical ability to deliver the information required for the ESIA and business case, but are presently neither systematic in coverage (both spatially and temporally) nor well-integrated with other technical areas such as water quality.

Typically, this issue is addressed through the preparation of an ESIA scoping report. Whilst there is a scoping report already, it is not comprehensive across all topic areas and being issued in 2008 is not reflective of the scheme as currently proposed and is unlikely to adequately consider the current environmental conditions. In addition, apparent omissions within the scope of the ESIA studies to date include:

- The 2008 scoping report rightly identifies the impacts on flora, especially mangroves, as a key area of investigation. The scope should also consider the loss of other habitats such as saltmarsh and dunes, the conversion to sub-tidal (outside the barrage) as a result of sea level changes, and the impact of saltmarsh loss due to the implementation of compensatory mangrove habitat.
- The impacts arising from the secondary developments associated with the barrage are omitted, such as the effect of large increases in population density stimulated by the presence of the barrage on water quality and ecological receptors. This includes largescale plans of land cover change and intensification of agriculture, leading to increases in run-off and eutrophication.
- The 2008 scoping report also identifies the impacts on a wide range of fauna as a key area of investigation and resolution. Whilst detailed scoping recommendations are made for some areas, in others the analysis is very

superficial. This scoping needs to be updated with the latest project design, including all associated facilities and infrastructure. The required studies must include receptors such as marine mammals, sea turtles, avifauna, and intertidal benthos, as well as terrestrial species and habitats.

- The effects of displacement of people engaged in sectors linked to the marine environment including the saltpan, agriculture and fishery need to be properly scoped and displacement effects fully assessed and resolved (See also workstream E).

As well as the incomplete scoping of topics to be considered in the ESIA, there is an absence of clear integration of studies that must link to each other. Principally these are the assessments of changes to water levels, water quality and morphology that fit in workstream B, and their interaction with marine and estuary environment receptors in this workstream. There are then knock-on implications for Workstream E where resources utilised by people may be affected, e.g. fisheries, or freshwater resources outside the dam area.

Possible mitigation:

The ESIA studies should be systemically scoped across all relevant receptors in accordance with the EIA Notification, 2006; taking into account the studies that have been undertaken since 2008. The scoping should include the interaction of secondary effects between different receptors. For example, the effect of water quality on ecology, and then to assess the effects at the population level, and address them.

Furthermore, the scoping must be related to the latest project concept, and encompass cumulative effects from other planned and consented projects in the area, and any secondary effects from, for example, the population growth stimulated by this and other largescale schemes.

The scoping should address the need for a substantial increase in baseline data acquisition. This will include updating the datasets from previous surveys and extending it to include, for example, marine sediment sampling within and outside the barrage, and ecological survey of areas within associated developments for the scheme such as quarries and/or dredging areas.

The scoping process must include sufficient consultation with external stakeholders and be responsive to their requests for amendments to the assessment approach.

Residual risk after mitigation:

Scoping the terms of reference of ESIA studies is a widely adopted practice including in India. It should therefore be possible to undertake a satisfactory scoping exercise to address the risks identified above. Therefore, whilst the presently identified risks in this area are high, the residual risk can be feasibly reduced to a low level by an updated programme of scoping.

7.3.2 Technical gaps in baseline understanding

Issue Description:

The general deficiencies of the scoping process that has been conducted for the ESIA studies are presented in Section 7.3.1 above. This section of the gap analysis focusses on the technical limitations in baseline understanding that are of greatest importance to marine and estuary environmental risks.

There is limited baseline understanding of the soil conditions in the terrestrial and sub-tidal areas. Sampling has concentrated in a few areas and will need to extend to all relevant land/intertidal areas, with more focus on likely impact areas. This will inform the assessment of the interactions with water quality following barrage enclosure, especially salinisation and eutrophication effects. Work to address this issue will require an updated definition of the areas to be affected by the project.

There is also insufficient baseline understanding of the water quality conditions and inputs from feeder rivers. Sampling data for input rivers is available for 2009-2014, but seemingly limited to one year for the Gulf beyond some physical parameter measurements. Addressing this is essential to inform the assessment of the water quality changes arising from barrage enclosure, and the subsequent effect on ecological and social receptors. There is an indication that dredging will be required within the project. However, details are required on the dredging location in order to define the sampling programme of potentially contaminated sediments to be dredged for dam construction or land reclamation.

The present and future status of mangrove forests is one of the most important environmental risks arising from the scheme. There are a number of reasonably comprehensive reports describing mangrove forests in the project area and beyond. However, there are apparent inconsistencies. For example, there is reportedly an increase in mangrove cover over time, which is partially attributed to agencies efforts in reforestation. Satellite images used in the mapping do not seem to tally with the ground-truth assessment of mangrove forest density. This has a very important bearing on the impact assessment and compensation requirement. Updated survey and subsequent analysis will need to be conducted with up-to-date satellite images.

The reports note the presence of areas of halo-tolerant and saline plants such as *Salicornia brachiata*, which is a saltmarsh species. Saltmarsh is typically of high ecological value and delivers many ecosystem services. Assessment should therefore be made of the presence and density of saltmarsh, as well as the presence of mangrove. The reports mention the presence of dunes and associated dune flora, however this is also not surveyed or mapped.

Whilst the baseline information relating to mangrove forests has been studied in some detail, the descriptions of the terrestrial and aquatic fauna (animals) is largely lacking. The exception being a high-level review of the fisheries of the Gulf of Khambhat but even this is insufficient for a sufficient assessment.

A more detailed assessment of the fisheries and aquatic ecology baseline, in terms of its biodiversity value (as opposed to a social resource), is required to understand the conservation value of the estuary itself and its importance as a migration route for species such as hilsa. It is recommended that the value of faunal species / assemblages (terrestrial and aquatic) and habitats are assessed according international Lenders standards for biodiversity (i.e. the determination of potential Critical/Natural Habitat, as part of a formal Critical Habitat Assessment). This

baseline analysis will inform the Project mitigation requirements (i.e. “no net loss” or “net gain” requirements for natural and critical habitat respectively).

There is very limited information on avifauna which is mostly derived from secondary data and some bird data from a few survey sites, which will not represent the majority of the impacted area. There is only limited sampling of intertidal and marine benthos, which will provide a food resource for avifauna. Without mitigation this alone is considered high risk because the intertidal areas are understood to be foraging and stop-over areas for internationally important bird species. An assessment of the intertidal areas as a feeding resource will be required and assessment of increased flight times for migratory birds, as a result of the intertidal area loss following dam closure.

There is a lack of information on marine turtle nesting areas and the use of the Gulf and surrounding area for marine mammals.

Overall, there is insufficient baseline for a full assessment of likely change in faunal community composition following the closure of the barrage and the resulting alterations to communities present.

Possible mitigation:

The mitigation of this risk is linked to the scoping recommendations above, as the required baseline studies can be addressed within a renewed scoping process. However, with respect to the technical robustness of the baseline, the following main recommendations are made.

A comprehensive sampling programme of the Gulf of Khambat, feeder rivers and adjacent land areas is essential. This should consider physical and chemical quality of the water and soils and take into account seasonal variability of the former. The existing sampling can be used to guide the developed of a suitable sampling programme.

Detailed habitats survey is also needed for all potentially affected areas (including areas outside the barrage affected by sea level changes), covering the type, condition and extent of habitats. It is recommended that data is collected in such a way that the value of baseline habitats (terrestrial and aquatic) can be assessed according to international standards for biodiversity (i.e., the determination of modified, natural or critical habitat, as defined by ADB / IFC biodiversity standards, as part of formal Critical Habitat Assessment). This should include an assessment of whether the estuary qualifies as Critical Habitat for hilsa and/or other migratory fish species.

This baseline habitat analysis will inform the mitigation requirements (i.e., “no net loss” or “net gain” requirement), as well as the impact assessment. This will require updated satellite images, and additional ground-based surveys and ground truthing of the remote sensing land-cover assessment.

Updating the mangrove data should include mapping and assessment of saltmarsh and dunes (and associated fauna) in the direct and indirect impact zones. Given the

importance of mangrove planting as mitigation, the project also needs a review of previous attempts to reforest mangroves in areas close to the project site.

A wide range of detailed faunal surveys (and complementary desk study research) are needed for all potentially affected areas, including assessment of the abundance and diversity of fauna present and consideration of seasonal variability. These will need to include seasonal avifauna survey of intertidal areas within the barrage area, and use of intertidal outside of the barrage closure and further afield that will be affected by tidal amplitude increases, predicted as a result of the closure. This should link in with assessment of the intertidal area as a food resource for birds, both inside and outside of the closure area. There is also a need to include baseline surveys of turtle nesting areas as well as use of the Gulf of Khambhat by marine mammals.

Residual risk after mitigation:

The baseline studies outlined here, which will need to be confirmed during the updated scoping stage, should not present any major technical obstacles provided they are scoped, planned and resourced properly. Owing to the need for surveys across multiple seasons and possibly years, these surveys will have an impact on the production times for the ESIA. Nonetheless, the residual risk to the project overall is considered low.

7.3.3 Limitations in the Impact Assessments

Issue Description:

Many of the limitations to the impact assessments that have been conducted to date can be linked back to the absence of a systematic scoping exercise and the issues identified above regarding the baseline requirement. Indeed, it is not clear from the available reports how the recommendations of the Scoping Report (2008) have been taken forward since then, noting the reservations of the MoEF, expressed in 2010.

The mangrove study quantifies the areas at risk, and is updated in the GES synopsis report. This appears to be based on the scheme as foreseen in c. 2010, and needs to be updated. As noted above, there is no consideration of saltmarsh or dune system effects.

The fisheries impact analysis is high-level and needs to be comprehensively updated and expanded based on detailed surveys and desk study screening. It needs to consider the latest proposed scheme, including the implications of the Narmada River diversion for hilsa (and other migratory fish/invertebrates) and their migration routes. It should be noted that there is the potential for significant impacts/loss of estuarine habitats used by these species, which likely qualify as natural/critical habitat under international biodiversity criteria. Typically, mitigation is required to demonstrate “no net loss” or “net gain” for natural and critical habitats respectively in order to secure international finance.

Likewise, other faunal effects such as upon marine mammals, avifauna and marine benthos are still not fully assessed, taking into account the (as yet not completely addressed) effects on the estuary physical regime.

A study in 2016 on the impacts of the project on water levels at nearby ports identifies effects on water levels, currents and bedload sediment. However, these are not evaluated in terms of impacts for the port operations. A separate study in 2018 appears to reach contradictory findings that need to be reconciled. Neither report considers the water quality effects within the barrage (except for salinity), with respect to eutrophication, accumulation of contaminants and related ecological effects for example. Contaminant accumulation may pose risks to the food chain if the impoundment is used for fish production.

There is a residual risk concerning the likely increased salinity of water sources to the south of the barrage as a result of alterations in flow and increases in tidal amplitude. This may affect the coastal habitat through submergence or salinity ingress in coastal aquifers, with subsequent human and ecological implications. There will also need to be further assessment of this knock-on increase in water levels and potential decrease in water quality outside the barrage area. Conversely, the reduction in salinity inside the barrage area may lead to an increase in waterborne disease vectors that will need to be assessed and mitigated.

The impacts assessments are focussed mainly on the physical footprint of the scheme but need to be integrated with the effects on parameters such as water quality and levels, and take into account secondary, indirect and cumulative effects.

Possible mitigation:

Full examination is needed of the direct, indirect, secondary and cumulative effects, informed by a comprehensive baseline, and supported by validated modelling of the effects on estuary water levels and morphology in and outside the barrage. It is critical that the assessment of ecological effects, for example, is informed by a sufficient assessment of effects on water quality. The assessment must consider the scheme as presently proposed, rather than previous iterations.

The assessment approach must be validated through scoping consultations with the regulatory authorities.

Residual risk after mitigation:

The delivery of a comprehensive technical assessment, which will need to be confirmed during the updated scoping stage, will be a major undertaking but should not present any technical obstacles provided it is resourced properly. However, once the assessment is updated, there remains the risk that effects on Critical Habitats for mangrove forest, migratory fish and birds, may remain significant unless adequate mitigation and compensation measures can be found. For this reason, the residual risk to the project overall is considered medium.

7.3.4 Environmental Mitigation and Compensation Strategy

Issue Description:

A project of this scale will lead to adverse effects requiring mitigation or compensation. Reaching consensus on the mitigation and compensation requirements relies on a robust and evidence-based assessment, using the steps outlined in the sections above. As this is presently lacking, there are substantial

gaps in the understanding of what level of mitigation and compensation measures are required. For example, the measures that will be required to mitigate the likely significant impacts on fisheries, avifauna, coastal habitats (other than mangrove) and marine benthos are largely omitted at this point.

Thought is given to mangrove restoration and compensation, given the importance of this issue. These plans need to be updated in view of the latest proposed scheme. The potential areas for mitigation of mangrove loss will need to be assessed against a climate change model and assessed against alterations to coastal processes as a result of having the barrage in-place. This could alter conditions outside the barrage closure area (e.g., water levels) that may indirectly affect further areas of existing mangrove, and areas identified for potential mangrove mitigation.

All of the preferred mitigation approaches will need to be substantiated by evidence on their effectiveness, and for this reason a review of previous mangrove restoration programmes is recommended. The mangrove restoration areas will need to be selected so as to be sustainable in the long term and the impacts of the restoration programme may themselves have impacts that may require mitigation.

Notwithstanding the potential habitat losses, it is likely that the Project will need to implement mitigation to facilitate the free passage of migratory fish and invertebrate species if it is to demonstrate “no net loss” or “net gain” for these migratory species. The adverse effect of the barrage on fish/invertebrate passage is noted in the documentation, but mitigation to enable fish passage, such as a fish bypass channel is not discussed. It is noted that such mitigation will need to be informed by water availability and quality and currently it is uncertain if such a measure could be effective.

Detailed quantification of the type and extent of habitats that will be lost is essential to inform the mitigation requirement. It is therefore reiterated that new data is collected to ensure the value of baseline habitats (terrestrial and aquatic) can be assessed according to international standards for biodiversity.

The effects on water quality within the barrage have been an issue of concern from the outset of the project development. It is critical that plans are in place to improve the river water discharges behind the barrage, to mitigate these water quality effects. However, there is no clear evidence of any steps planned in this regard other than relocation of water waste discharges seaward of the barrage. This will have consequential impact upon the marine environment and further mitigation will be needed.

Possible mitigation:

A robust mitigation and compensation plan should be prepared, based on:

- Quantified and delineated descriptions of the impacts upon all relevant receptors (natural/critical habitat areas, faunal populations etc)
- Identification of the available mitigation approaches, adopting the mitigation hierarchy (avoid, minimise, reduce, compensate)
- Evaluation of the practicality and effectiveness of the available mitigation approaches, in the long term (e.g., mangrove restoration / fish passage)

- Consultation with regulatory authorities on the adequacy of these measures
- Incorporation of the technical and cost requirements of the preferred measures within the overall business case for the scheme.

Residual risk after mitigation:

The barrage will likely have large and wide-ranging impacts. The development of practical and effective long term mitigation measures is therefore an essential activity. However, the scale and nature of these likely effects have so far only been partially defined with respect to mangrove forests, and largely undefined in most other areas and habitats.

The development and agreement of these measures can only be progressed hand-in-hand with the preceding steps of the ESIA, and as outlined above there are significant gaps in these areas. There remains considerable uncertainty about the scale of the mitigation and compensation measures required, and their practicality and effectiveness. The full financial cost of these measures is therefore not fully identified.

In principle, the approaches outlined in this chapter to investigate these uncertainties are quite feasible, albeit time consuming and requiring adequate resources and expertise. These studies may however conclude that adequate measures to mitigate or compensate for effects upon natural/critical habitats cannot be delivered with certainty or are technically unfeasible. As the ability to deliver effective mitigation and compensation has cost and feasibility implications for the overall business case, but is presently not evidenced, this issue is considered a medium to high residual risk to the project.

7.3.5 Compliance with international funding requirements

Issue Description:

International funders have policies that require the protection of the environment and people from a project's potential adverse impacts by avoiding adverse impacts where possible; and otherwise minimising, mitigating, and/or compensating for adverse project impacts on the environment and affected people when avoidance is not possible. Regardless of whether international funding will be needed, these policies provide a useful benchmark for the project.

By reference to the ADB's safeguard policies for example, as outlined above, many of the major impacts of the project still need to be fully assessed and addressed, including estuary physical regime, water quality, many ecological impacts (mangrove, fisheries etc), and waterborne disease vectors.

As there may be effects on marine and estuary resources and attributes utilised by the ports sector, agriculture, salt production and marine fishing, there is also a knock-on issue for direct and economic displacement of people - refer to Workstream E.

Once these effects have been properly quantified, measures also need to be put in place to address them. In terms of ecological effects, this will mean achieving a net gain in biodiversity.

Possible mitigation:

A comprehensive ESIA should be developed to international standards e.g. of the ADB, addressing all of the areas mentioned in the preceding sections of this chapter.

Residual risk after mitigation:

The production of the complete ESIA to a standard acceptable by international funders should, in principle, be possible. The expectation of funders will be that the mitigation and compensation measures are built into the business case, such as net gain for biodiversity.

However, at present and for the reasons stated in previous sections, there is presently low certainty that steps can be taken to address all of these requirements, especially with regard to the delivery of satisfactory mitigation and compensation. Therefore, this issue is considered a medium to high residual risk to the project.

7.3.6 Sustainable solution

Issue Description:

Looking at the project as a whole and its implications for the marine and estuary environment, there is no evidence that an evaluation has been made of the available options; and whether the currently proposed project is the most sustainable solution, in any respect other than the capacity to deliver a sufficient amount of water from the feeder-river systems.

To reach a degree of national and international acceptance, it is therefore recommended that an appraisal of the available options is made, by reference to the UN Sustainable Development Goals (SDGs). The SDGs are a comprehensive list of global goals integrating social, economic and environmental dimensions of development. These goals have been widely adopted as the benchmark for project legitimacy and appropriateness for financing.

Possible mitigation:

Conduct an objective 'fair basis' evaluation of whether this project represents the most sustainable approach to delivering project aims, by reference to the SDGs.

It is stressed that the alternative options considered should be capable of delivering the currently envisaged project aims.

Residual risk after mitigation:

There is no reason in principle why such an option evaluation cannot be conducted. However, in the absence of such a review there is high uncertainty that the outcome would be that this project represents the most sustainable approach. This issue is therefore considered high risk.

7.4 Remaining high risk gaps

There are no other high-risk gaps that are not already described in this chapter.

8 E - Socio-Economic Impacts

8.1 Key High-Risk Gaps

8.1.1 Comprehensive Integrated Social Impact Assessment (SIA)

Issue Description:

A comprehensive integrated Social Impact Assessment (SIA) has not been carried out. Although several studies assess different social aspects of the project, an integrated assessment with a common objective is lacking. Being a complex project, it has many (sub) components that may lead to changes in people's livelihoods and living conditions. These potential negative and positive impacts and mitigation measures according to the mitigation hierarchy are not in place.

Possible mitigation:

SIA should be performed. Past, present and future impacts and risks should be identified. The risks and impacts should be presented for each phase of the project (construction, transition, operation). As a minimum, the following items should be included in SIA:

- Direct or indirect impacts occurring at the project site or in the wider area of influence. Indirect impacts include the side effects of the project given the complexity of the social processes and the interrelationships between the social components.
- Analysis of alternatives.
- Immediate triggered adverse impacts as well as longer term impacts.
- Cumulative effects that occur through interaction with other developments at the project site (as well as in the wider influence area).
- Stakeholder mapping

In addition, the assessment should consider the principles of social sustainability and the Sustainable Development Goals.

Residual risk after mitigation:

If the possible mitigation measures were successfully implemented, most of the risks and impacts could be avoided and mitigated. However, in the short and medium term, impacts on the livelihoods of certain groups (e.g. salt collectors, simple fishermen) may be unavoidable. Therefore, the project should identify livelihood sources and highlight basic living conditions. Consistent social monitoring is critical to track changes. The complexity of the project may lead to indirect impoverishment risks, which should be mitigated by introducing livelihood restoration programs and supporting adaptation to the new socio-ecological environment.

8.1.2 Receptors Identification and Engagement

Issue Description:

Potential sensitive social receptors haven't been identified or weakly presented. Particularly, the reports are silent on assessment of impacts on indigenous people, nearby businesses, vulnerable groups, cultural facilities.

Possible mitigation:

In general, it is necessary to map out the stakeholders and create a plan for engaging them at different stages of the project. The views and preferences of stakeholders (especially key stakeholders) should be incorporated into project planning and sub-component preparation.

An Indigenous Peoples Assessment, which should identify potential impacts and risks, needs to be undertaken. Perceived risks and preferred mitigation measures should be assessed.

Residual risk after mitigation:

Generally, it is necessary to map the stakeholders and create a plan to involve them in the various stages of the project. The views and preferences of stakeholders (especially key stakeholders) should inform project planning and sub-component preparation, and an Indigenous Peoples Assessment needs to be undertaken that identifies potential impacts and risks. Perceived risks and preferred mitigation measures should be assessed.

Indigenous peoples and marginalized groups should be monitored and the project must be prepared to take appropriate corrective actions.

8.1.3 No Gender Assessment

Issue description

No gender assessment has been carried out. Potential negative impacts of the project from a gender perspective and ways to incorporate gender benefits were not discussed. Beyond avoiding negative effects, a gender impact assessment can also be used in a more transformative way as a tool for defining gender equality objectives and formulating the policy to proactively promote gender equality.

Possible mitigation

A gender assessment should be conducted, and a Gender Action Plan (GAP) should be prepared. Specific gender elements should also be included in the project for better project implementation.

The objectives of the GAP are:

- Promoting women's participation in the project;
- Maximizing women's access to project benefits;
- Minimizing social vulnerability of women arising due to the project activities like securing land, security concerns during construction

Residual risk after mitigation

Due to the role of women in society or other socio-structural barriers, women may not be able to reap the benefits of the project if they are not encouraged or included in targeted assistance. Women's voices should be heard at all stages of the project through focus group discussions, individual interviews, confidential grievance mechanisms, etc.

8.1.4 No Labour Assessment

Issue description

No assessment of labour impacts has been undertaken (e.g. risks of labour influx, measures to avoid child labour, forced labour, possible loss of jobs), etc. The nature of the project may lead to labour migration and structural changes in the labour market, as well as influence the supply and demand situation.

Possible mitigation

To meet international donor requirements and align with good international practise, a work assessment and specific action plan are critical. Such a plan should also include a work- specific (occupational related) grievance mechanism.

Residual risk after mitigation:

Risks can be mitigated if appropriate plans are made and implemented. However, continuous monitoring is required throughout the project. During the construction phase, occupational health and safety should be the focus. During the transition and operational phase, residual impacts could occur in the form of structural changes in the labour market and transition to a new employment situation in the project area.

8.1.5 Archaeology and Cultural Heritage Impact assessment

Issue description

The Reports are silent about the risks & impacts on archaeology and cultural heritage.

Possible mitigation

SIA should include baseline, potential impacts and risks to archaeology and cultural heritage. Relevant mitigation measures to be identified.

Residual risk after mitigation:

A significant portion of the risks can be avoided through alternative project designs/elements. However, the remaining risks, such as restricting access to cultural heritage sites can be mitigated by working closely with the relevant key stakeholders. Impacts to culturally and architecturally significant sites may delay project activities by facing opposition groups and/or regulatory requirements.

8.1.6 International Standards

Issue description

Impacts and risks of land acquisition and resettlement, potential loss of access to natural resources, associated monitoring and reporting requirements are lacking. International standards and performance requirements should be followed in identifying risks and preparing appropriate plans.

Possible mitigation

Impacts and risks of land acquisition and resettlement, potential loss of access to natural resources, associated monitoring and reporting requirements are not present. International standards and performance requirements should be followed in identifying risks and preparing appropriate plans.

Residual risk after mitigation:

Land acquisition and loss of access to natural resources (fishing sites, salt collection points, access to the open sea) can have a negative impact on livelihoods and lead to impoverishment risks. Continuous monitoring is essential. In addition, the project should make use of external monitoring (preferably after 1 and 3 years) to assess the impact of such plans and determine the necessary corrective measures.

9 F - Transport cost benefit analysis

9.1 Key High Risk Gaps

9.1.1 Transport Report

Issue Description:

A Traffic Assessment has been provided, focusing on road traffic only. No analysis of a multi-modal transport baseline, forecast flows, opportunities and impacts has been undertaken.

Possible mitigation:

Develop a comprehensive multi-modal Transport Assessment and baseline.

A Transport Business Case for Investment Report should also be produced, containing the following information:

- Strategic Case:
 - Strategic context
 - Organisational overview
 - Business strategy and aims
 - Other relevant strategies
 - The Case for Change

- Spending objectives
 - Existing arrangements
 - Business needs – current and future
 - Potential scope and service requirements
 - Main benefits and risks
 - Constraints and dependencies
- Economic Case:
 - Critical Success factors
 - Long-listed options
 - Preferred Way Forward
 - Shortlisted options (including the “Business As Usual (BAU)” and ‘do minimum’)
 - NPSC/NPSV findings
 - Benefits appraisal
 - Risk assessment
 - Sensitivity analysis

The above should be integrated into the wider Financial, Commercial and Management for the scheme.

Residual risk after mitigation:

By developing a more in-depth understanding of the regional transport needs and impacts and opportunities that Kalpasar would bring to the region, it is possible to strengthen the benefits ration in the Cost-Benefit Assessment for the overall project.

9.1.2 Outdated Traffic Assessment

Issue Description:

The Traffic Assessment was undertaken in October 2013. Any data, references and guidance documents detailed within the report may no longer be pertinent. The traffic assessment only refers to vehicle users but there is no assessment of rail use.

Section 3.6 considers the potential impacts of several major infrastructure projects on the proposed Kalpasar Dam. Since the production of the 2013 transport report, a number of these projects (or phases of these projects) have become operational. These projects may also have changed in scale, detail etc. since production of the transport report.

Possible mitigation:

Update the Traffic Assessment, ideally to a 2019 baseline to represent the latest pre-COVID-19 travel patterns. Include assessment of present and potential rail users. If no directly applicable data is available (as there is currently limited rail connectivity in the region, include an assessment of similar regions and impacts of similar connectivity projects.

Residual risk after mitigation:

The impact of COVID-19 on long-term travel behaviour is currently unknown. Any future forecasts undertaken at this time may therefore not be representative of future travel patterns post-pandemic. It is recommended that multiple future scenarios are considered in order to fully assess different potential levels of travel demand and subsequent impacts.

Due to the Traffic Assessment being undertaken in 2013, a number of datasets, references and guidance documents detailed within the report are outdated, including the following:

- Traffic surveys;
- Industry trip generation surveys;
- Toll revenue data;
- Willingness to pay surveys;
- Socio-economic data; and
- Traffic growth rates.

Similarly, the report considers potential cumulative impacts of several major infrastructure projects. The status of these projects will have changed since the original report was produced, and additional major projects may have arisen. The subsequent impacts of these changes will need to be considered.

9.1.3 Economic Viability & Strategic Case

Issue Description

The transport crossing has been assessed in terms of economic costs and benefits over a 40 year horizon, discounted back to give an Expected Investment Rate of Return (EIRR), which at the time of analysis needed to be 12% to pass the Government of India and World Bank criteria for investment. The 2013 study, with a price base of 2010, concluded that the transport crossing is a viable investment with the lowest EIRR of all scenarios tested being 59.84%.

However, the economic viability of the new transport corridors created by Kalpasar was not assessed for the full project life. The costs included capital construction estimates, assuming a 5 year construction duration after completion of the dam, with a 20% spend each year to completion. Transport forecasts were projected 40 years into the future and capacity requirements checked against the proposed 8 lanes. However, no projections or checks on capacity past 40years were reported.

The capital costs included are for the road surfacing only on top of the existing dam. This most likely underestimates the costs since the dam cross section and crest

height will have to be increased due to safety requirements for the road; these costs were not included.

Similarly the O&M costs include for maintenance of the road surface and operation of the toll plaza only; no provision is made for the maintenance of the dam in terms of transport links.

Recommendations

Develop a Transport Business Case for Investment Report – as described in Section 9.1.1

Integrate the above into the wider scheme Financial, Commercial and Management for the scheme as a whole.

Residual Risk after Mitigation

The economic case for the transport link may not be sufficient to support the construction of the dam itself, but it can act to support the overall Cost-Benefit Analysis and Project Business Case.

9.1.4 Risk Assessment

Issue Description

No risk analysis has been undertaken on the traffic data analysis or the economic value assessment. The project risk, including data and modelling uncertainties in the predicted demand and costs, should be identified and quantified. A proposed mitigation strategy should be developed following the eliminate-reduce-mitigate hierarchy approach.

Recommendation

Undertake a full Risk Assessment - covering Transport, rather than just traffic, and propose mitigation strategies.

Residual Risk After Mitigation

The uncertainty around the business case will be reduced but there is no guarantee that the business case will still be viable.

9.1.5 Construction Traffic

Issue Description:

At present there is no construction development plan or finalised estimates for the quantities of materials required. No assessment has been undertaken of the forecast construction traffic. The impact on local infrastructure during the construction duration has not been assessed. A project of the scale of Kalpasar can considerably increase the strain on local infrastructure.

Recommendation:

Develop a Construction Traffic Management Plan. Assess local existing infrastructure and consider developing new capacity where required.

Residual risk after mitigation:

Potential significant adverse impacts arising from construction traffic. However, these would be expected to be sufficiently mitigated through the implementation of the Construction Traffic Management Plan.

10 Conclusion

The Kalpasar project feasibility has been studied over the past 40 years from various perspectives, such as the technical solution of the dam to the environmental impacts. Data and knowledge have been developed in different levels of detail. The reports and studies in the scope for this Gap Analysis were reviewed by each work stream for their relevance and quality, within the framework set out in the Inception Report.

After the completion of the Gap Analysis by Arup, it was concluded that there are several overarching themes across the gaps identified across all workstreams. Those are summarised below.

- There is lack of clarity on the definition on the Project Aims and Needs, Project Design Brief, Design Limit States and Design Standards
- There is not appeared to be any design integration between the different studies to produce a single coherent design. There is lack of continuity between reports, and there is lack of reference to the project objectives.
- There is lack of clarity of how project decisions thus far have been made and different options evaluated
- Many of the studies provided are out of date and would need updating with most up-to-date available data and currently proposed alignment
- There is no one database or an information model collating and comparing the available data (from carried out surveys) for the existing site and the proposed scheme.
- There is little assessment done on the stakeholders and receptors for the scheme. There is no clarity if any engagement with the potential stakeholders have been made.
- There is little information on how the scheme would impact the wider region and how that affects the region development plans and vision
- There is no up to date analysis of the Costs and Benefits of the Project.

Recommendations and mitigations have been made for addressing the identified gaps. While addressing the gaps will reduce the overall project risk, some of the identified issues, even after mitigation, have the potential to lead to significant cost and time impacts on the project and put the feasibility under review.

Appendix 1 Kalpasar Report Check List

The following table shows the reports for studies complete, ongoing and to be carried out. It highlights whether these have been received yet at the time of this review.

No.	Package Name	Status	Received	Included in the original 38 Reports
1	Techno Economical Feasibility Report Including Haskoning Report	Complete	Yes	Yes
2	Conceptual and Structure Plan and Preparation of Base Map of Kalpasar Project Area	Complete	Yes	Yes
3	Legal Opinion	Complete	Yes	Yes
4	Topography Survey 0 to 10 m contour along peripheral area of reservoir.	Complete	Yes	Yes
5	Bathymetry Survey for entire GoK	Complete	Yes	Yes
6	Traffic_Assesment_Study_GoK	Complete	Yes	Yes
7	Geo physical survey for revised dam corridor 2010 & 2014	Complete	Yes	Yes
8	Water Sampling and Water Quality Monitoring Program	Complete	Yes	Yes
9	Estimation of PMF, Design flood including determining spillway capacities	Complete	Yes	Yes
10	Groundwater conditions in Kalpasar Command area in Saurashtra	Complete	Yes	Yes
11	Water availability study for Kalpasar project main report	Complete	Yes	Yes
12	Vetting of Water Availability Studies for Gulf of Khambhat Development Project (Kalpasar)	Complete	Yes	Yes
13	Study on sea-level changes, global warming and regional climate	Complete	Yes	Yes
14	Impact of Kalpasar Project on the existing and Proposed Ports	Complete	Yes	Yes
15	Impact of Tsunami	Complete	Yes	Yes
16	Impact of Storm surges, wind waves and seiches	Complete	Yes	Yes
17	Design of spillway report 2018	Complete	Yes	Yes
18	Primary and alternate locations of Spillway 2 DT 2014	Complete	Yes	Yes
19	Primary Dam cross sections were finalized during 3 DT 2015	Complete	Yes	Yes

20	Hydrodynamic and sediment model studies and related measurements	Complete	Yes	Yes
21	Fisheries Study	Complete	Yes	Yes
22	Study of taluka-wise Irrigation planning and Agro-economic impact of Kalpasar project in coastal areas of Saurashtra region	Complete	Yes	Yes
23	A study on positive irrigation impact of Kalpasar reservoir project in Saurashtra region of Saurashtra	Complete	Yes	Yes
24	A study of agronomical constraints in agriculture in the command area of semi-arid and arid region of Saurashtra	Complete	Yes	Yes
25	Irrigation facilities	Complete	Yes	Yes
26	Assessment of Baseline Environmental quality and social status of Kalpasar Project	Complete	Yes	Yes
27	Present Status of Salt Pans and Assessment of Social, Economic and Environmental Impact of the Kalpasar Reservoir Project	Complete	Yes	Yes
28	Impact on mangroves consequential to creation of Kalpasar reservoir and mitigation strategy	Complete	Yes	Yes
29	Scope of Work for EIA & SIA Studies	Complete	Yes	Yes
30	Synopsis of the environmental and socioeconomic aspects of the various studies related to Kalpasar project	Complete	Yes	Yes
31	Reclaimable land plan GIS data base	Complete	No	Yes
	Renewable Energy	Complete	Yes	No
	Reference_Report_CWC_Guidelines_for_Preparation_of_DPR_for_Irrigation_And_Multipurpose_Projects	Complete	Yes	No
	Reference_Report_Six Speific Studies Kalpasar	Complete	Yes	No
1	Establishment & Monitoring of Seismological Observatories	Ongoing	No	Yes
2	Geotechnical Investigation and Survey along Dam Alignment	Ongoing	Yes	Yes
3	Water Quality Monitoring and diversion effluent studies	Ongoing	Yes	Yes
4	Desk wave flume studies for design c/s	Ongoing	Yes	Yes

5	Physical model study break water alignment.	Ongoing	No	Yes
6	Mathematical model studies for wave tranquility	Ongoing	No	Yes
7	Hydraulic model studies	Ongoing	No	Yes
1	Design of Dam, spillway, sluices, gates, breakwater structures and any other allied structures, stability of dam.	To be completed	No	No
2	Foundation compressibility studies for estimating the extra quantities of dam construction materials	To be completed	No	No
3	Detailed Construction Material Survey and transport facilities	To be completed	No	No
4	Survey investigation and design of Narmada Diversion Canal	To be completed	No	No
5	Survey investigation and design of Irrigation Canal, Pumping Stations & Allied Structures	To be completed	No	No
6	Detailed Studies on Wind Solar Power Plant	To be completed	No	No
7	Existing proposed Drinking Water supply scheme	To be completed	No	No
8	Existing proposed Industrial Water supply scheme discuss Kalpasar	To be completed	No	No
9	Hydrological, Meteorological & Hydro Geological	To be completed	No	No
10	Arrangements for offtake of reservoir water (by canals/ lift schemes) locations, capacities and main canal alignments	To be completed	No	No
11	Closure Techniques for construction of dam	To be completed	No	No
12	Inundation area on downstream of Kalpasar dam and Effect on sub soil water table in the adjoining area particularly downstream of the dam	To be completed	No	No
13	EIA/SIA study	To be completed	No	No
14	Flood Control	To be completed	No	No
15	CRZ Clearance proposal	To be completed	No	No