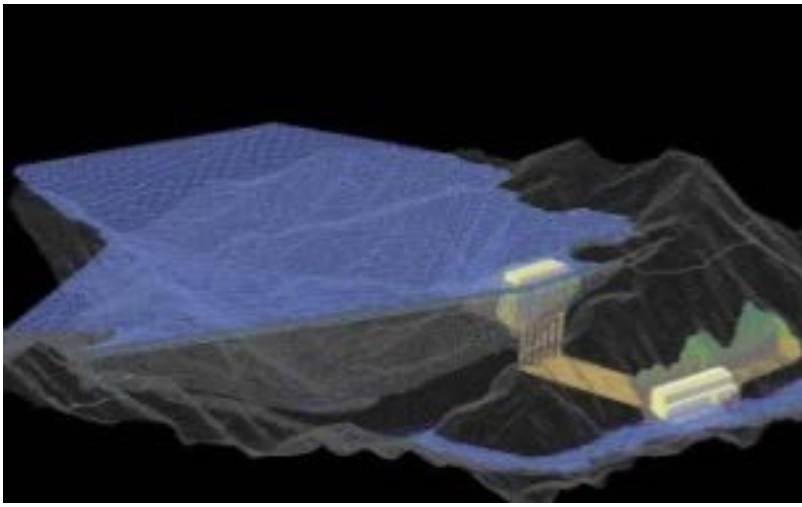
GHD Experience



Concrete Faced Rockfill Dams

Identifying the need

The design and construction of Concrete Faced Rockfill Dams (CFRD) has improved substantially during the last 40 years. This type of dam has proven to be a safe structure long term and is well suited to withstand static and dynamic earthquake loading. In some circumstances CFRDs can offer a cost-effective alternative in both wide and narrow valleys compared to other types of rockfill and concrete dams.

Compared to other types of dams, CFRDs offer advantages that include:

- Foundation grouting does not affect the critical path activities, since the grout curtain is located on the upstream side of the CFRD embankment
- CFRDs have historically performed well during earthquakes
- CFRDs with heights exceeding 150 m have been constructed at numerous sites
- CFRDs are able to perform well even if large leakages occur through the upstream concrete face
- CFRD construction offers a cost effective solution for many sites
- Rockfill of various quality can successfully be included in construction of the CFRD embankment

Service offering

GHD can offer the following professional services associated with CFRD analysis and design:

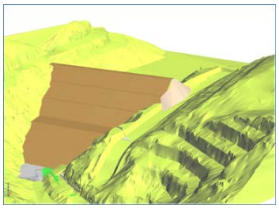
- Geotechnical site investigations, including evaluation of foundations and identification and testing of construction materials
- Concept design for new projects or upgrades
- Detail design for new CFRDs and upgrades
- Construction support
- Hydrological analysis
- River diversion
- Spillway design
- Structural analysis
- Access layout
- Safety evaluation of CFRD and other dams, spillways, outlet works, gates, valves, and penstocks
- Mechanical control equipment for dam outlet works
- Preparation of operation and maintenance manuals and dam safety emergency plans
- Economic evaluation of installations
- Environmental studies and engineering
- Carbon management

Benefits

Our extensive range of capabilities in dam design and related fields allows us to draw on a wealth of experience to satisfy specific project objectives. We have ready access to a global network of 8500 dedicated professionals. Expect to have access to the best people for your project.

Experience

GHD has worked closely with clients to respond to their needs for water projects. Examples of CFRD projects are described below.

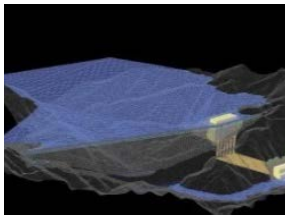


Kangaroo Creek Dam, Adelaide, South Australia

Kangaroo Creek Dam is a 64.5 m high CRFD with a side channel spillway. The project involved the design of an upgrade to the dam up to current standards and compliance with relevant dam safety guidelines. The upgrade comprised providing additional spillway capacity by increasing the length of the spillway crest and raising the embankment crest level to safely pass the Probable Maximum Flood, improving the ability to handle leakage through the upstream concrete face slab, providing a stabilising berm for improved resistance to extreme seismic loading and extending the existing outlet works.

GHD provided site investigation, detailed design and documentation services including:

- Geological mapping and intrusive site investigations and laboratory testing
- Seepage and stability analysis of the raised rockfill embankment
- Design of extensions to the face slab and new vertical and perimetric joint extensions
- Upgraded waterstop design for the existing vertical and perimetric joints
- Design of the permanent works staging to function as a coffer dam
- CFD and physical modelling of the spillway
- Optimisation of the spillway widening to minimise excavation and concrete volumes
- Assessment of the spillway cut batter slope to optimise excavation and rock support
- 3D finite element analysis of the Left Abutment Block
- Design of the extended outlet works
- Design of a new spillway flip bucket and plunge pool
- Analysis and design of the widened spillway chute
- Design of post tensioned anchors to stabilise the existing spillway crest structure
- Design of new electrical, security and ventilation systems



Baleh Hydroelectric Project Prefeasibility and Feasibility Study, Malaysia

As part of the Sarawak Corridor of Renewable Energy, GHD was engaged to undertake the prefeasibility and feasibility studies for the Baleh HEP. Based on site investigations, an options study and an optimisation process, the following arrangement was adopted:

- 220 m high CFRD, or RCC as an alternative
- Diversion works (45 m high upstream coffer dam and twin 12 m dia tunnels)
- An ungated spillway to pass the PMF discharge of approximately 28,900 m³/s
- 100 m high power intake structure
- Five 8 m diameter power tunnels leading to five 259 MW Francis turbines with total installed capacity of 1,295 MW generating 9,200 GWh/year

GHD was responsible for the geotechnical investigations, flood hydrology, sedimentation studies, CFRD and RCC dam design alternatives, diversion works design, spillway and plunge pool design and design of the 100 m high power intake structure and 8 m diameter tunnels leading to the powerhouse.

Bakun Dam, Sarawak Province, Malaysia

GHD undertook a CFRD dam design for a D&C Contract for the 205 m high Bakun Dam. The services included:

- Evaluation of site geology and availability of construction materials, including rockfill and natural filters
- Tender design of the dam, spillway, river diversion works and hydropower intakes
- Review of design, construction feasibility and reliability of power supply
- Assist the Contractor to establish materials quantities, construction methods, etc.

Shanxi Dam, Whenzhou, Zhejiang Province, Peoples Republic of China

The project involved the design and construction of a 135 m high CFRD funded by the Asian Development Bank for a 200 MW hydro scheme. The works comprised the construction of more than 5 million m^3 of rockfill, 3 km of tunnels, roads, power station and a 25,000 m^3/sec gated spillway. Housing, village construction and commercial redevelopments were constructed for the population displaced by the dam.

GHD provided independent audit and review of the design and construction of the project on behalf of the Asian Development Bank.

Little Para Dam Upgrade, South Australia

Little Para Dam was completed in 1977 and is a 53 m high concrete faced, zoned rockfill structure located on the Little Para River, 22 km northeast of Adelaide in South Australia.

GHD was engaged by SA Water to undertake a Safety Review incorporating concept design of upgrade options and subsequent detailed design in 2007 to increase the spillway capacity and improve stability of the existing spillway structure. The project included:-

- Raising the existing 225 m long dam crest parapet wall by 1 m
- Excavation of a 30 m deep, 360 m long and 52 m wide auxiliary spillway channel
- Construction of a 12 m wide concrete sill with 6.5 m high Hydroplus Fusegates
- A cement grout curtain to control seepage beneath the overflow sill.
- Access roads to cross.

Corella Dam, Queensland, Australia

GHD was the designer of Corella Dam in the 1950s and has had a constant involvement with the project throughout its operational life. The dam is a 23 m high shotcrete-faced rockfill dam which was constructed to provide the water supply for the Mary Kathleen uranium mine and township. More recently, GHD has provided the services including undertaking a safety review, failure impact assessment, design of upgrade works to provide increased spillway discharge capacity, advice on repairs for the shotcrete face slab, and five-yearly comprehensive dam safety inspections.

Cooby Dam, Queensland, Australia

Cooby Dam is a 32 m high concrete-faced rockfill dam constructed in the 1930s. GHD has been involved in many projects at Cooby Dam over the last 25 years including dam safety reviews and inspections, advice on repairs for the concrete face slab, failure impact assessment, assessment of acceptable flood capacity, and concept design of options for upgrade works to provide increased spillway discharge capacity.

Ruataniwha Water Storage Scheme, New Zealand

The Ruataniwha Water Storage Scheme is a multi-purpose irrigation and hydropower project proposed for the Hawkes Bay area, North Island, New Zealand. The scheme is to provide a reliable water supply for 6,000 ha of existing irrigation and an additional 20,000-30,000 ha of irrigation and a hydropower station with a generating capacity of approximately 6 MW.

GHD was responsible for geotechnical investigations, tender design of the dam, associated structures (diversion works including coffer dam and tunnel, spillway and intake structure), river offtakes and irrigation distribution system. Concept designs included clay core rockfill, CFRD and hardfill dam types for an 83 m high dam. Management of seismic risk was a key consideration and the project design required that the dam withstand a seismically-induced foundation displacement of up to 0.5 m and a Peak Ground Acceleration (PGA) of 0.85 g for the Maximum Design Earthquake (MDE).

Awoonga Dam Acceptable Flood Capacity Upgrade (Gladstone), Queensland

Awoonga Dam is a 50 m high CFRD dam which includes a concrete gravity main spillway, a low earth saddle dam and a series of natural saddles on the left abutment. GHD was engaged by Gladstone Area Water Board to undertake an initial failure impact assessment of the saddle dam on the left abutment which led to an upgrade options assessment of the various dams and spillway options to meet AFC requirements. GHD was subsequently engaged to undertake the concept and detailed design of a three stage upgrade works package.

Borumba dam Upgrade Options Study, Queensland

A study was carried out to identify technical challenges, risks, advantages and comparative costs of various prefeasibility design options to upgrade the Borumba CFRD Dam. The dam was to be upgraded to safely pass at least 65% of the required Acceptable Flood Capacity (AFC) by 2025 and 100% of AFC by 2035. The study compared options to raise the CFRD with augmentation of the spillway capacity. In addition, replacing the dam with a new RCC dam and increasing the yield was also considered. Six options were identified, including raising of the dam crest, widening of the spillway, provision of a new spillway, increasing the full supply level and replacing the dam with a new dam.

Experienced CFRD Personnel

Peter Ballantine

Peter has 35 years of experience in engineering, mostly related to dams and hydropower projects. Peter has been involved in the following CFRD Dams:

- 65 m high Berg River Dam, South Africa, design manager for detailed design
- 150 m high Polihali Dam, Lesotho, feasibility study design
- 115 m high Maguga Dam, Swaziland, tender design and specifications

Malcolm Barker

Malcolm has 35 years of experience in dams and hydropower engineering projects. Malcolm has been involved in the following CFRD Dams:

- 83 m high Ruataniwha Dam, feasibility design
- 200 m high Baleh Dam, feasibility and prefeasibility studies
- 25 m high Corella Dam, Queensland, spillway upgrade, detailed design and specification
- 205 m high Bakun Dam, Sarawak, Malaysia, review of D&C tender stage design
- 145m high Mohale Dam Lesotho, preliminary design
- 63.5m high Mazwikadei Dam, Zimbabwe, preliminary design to determine dam type

Manoj Laxman

Manoj has 35 years of experience in engineering, mostly related to dams and hydropower projects. Manoj has been involved in the following CFRD Dam:

- 90 m high Mukorsi Dam, Zimbabwe, pre-feasibility study, feasibility study, foundation investigations, detailed design, specifications and drawings

Bob Wark

Bob has over 50 years of experience in dams engineering projects. Bob has been involved in the following CFRD Dam:

- 135 m high Shannxi Dam, Peoples Republic of China, independent audit and review of design and construction on behalf of the Asian Development Bank

Brian Forbes

Brian has over 45 years of experience in dams engineering. Brian has been involved in the following CFRD Dams:

- 80 m high Mangrove Creek Dam, Australia, design and construction
- 45 m high Awoonga Dam, safety review

John Potts

John has over 40 years of experience in construction engineering of water supply schemes, including dams and pipelines. John has been involved in the following CFRD Dam:

- 80 m high Boondooma Dam, Australia, construction supervision

Dr Mark Locke

Mark has over 20 years of experience, principally in dam design, safety evaluation and construction. Mark has been involved in the following CFRD Dams:

- 205 m high Bakun HEP, Tender Design
- 220 m high Baleh HEP, Feasibility Study Design
- Feasibility studies of CFRDs in the Canadian Arctic

To contact our dams service line professionals, visit www.ghd.com/dams