ROLE OF HYDRO IN MODERN SUSTAINABLE POWER GRIDS

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W.I.S.E.

INTRODUCTION

TOPICS:

- Features of hydro developments
- Comparison with other renewables
- Contributions to grid performance
- Challenges to hydro
- Is hydro sustainable?

FEATURES OF HYDRO DEVELOPMENTS

- Hydrologic regime
- Site topography and development concepts
- Multipurpose developments
- Run-of-river versus storage projects

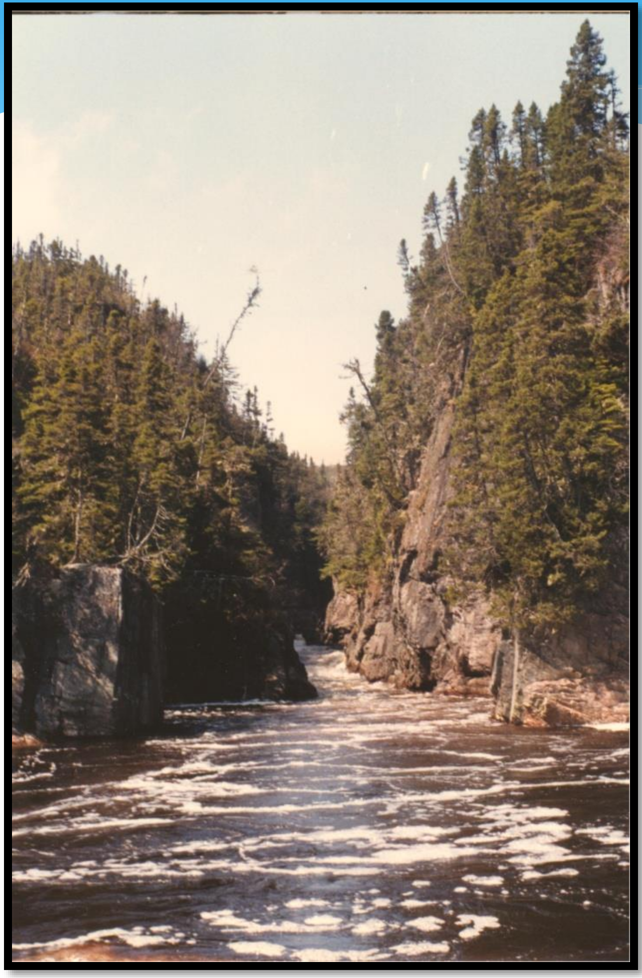
HYDROLOGIC REGIMES

Humid Zone:
Rio Sabanilla,
Ecuador

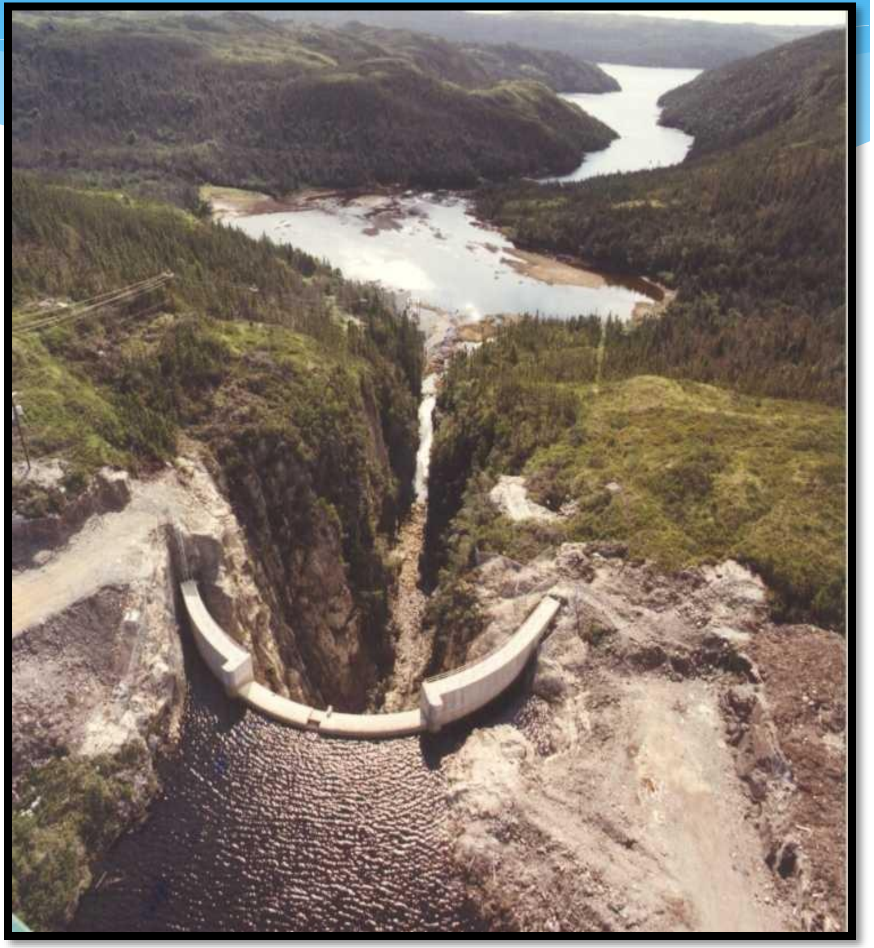
HYDROLOGIC REGIMES

Arid Zone:
Snare Lake
NWT.

CANYON SITE

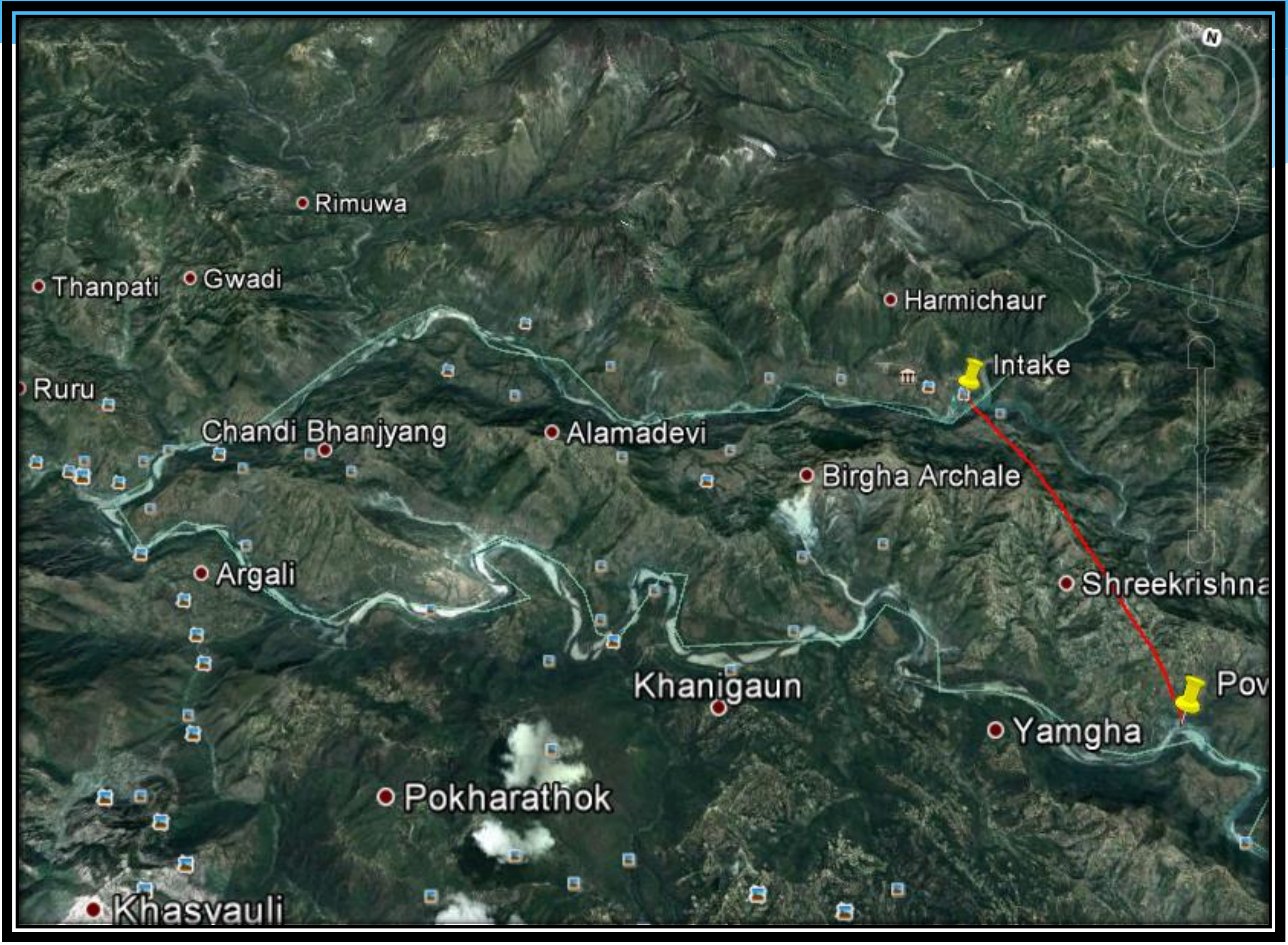


PRE-CONSTRUCTION



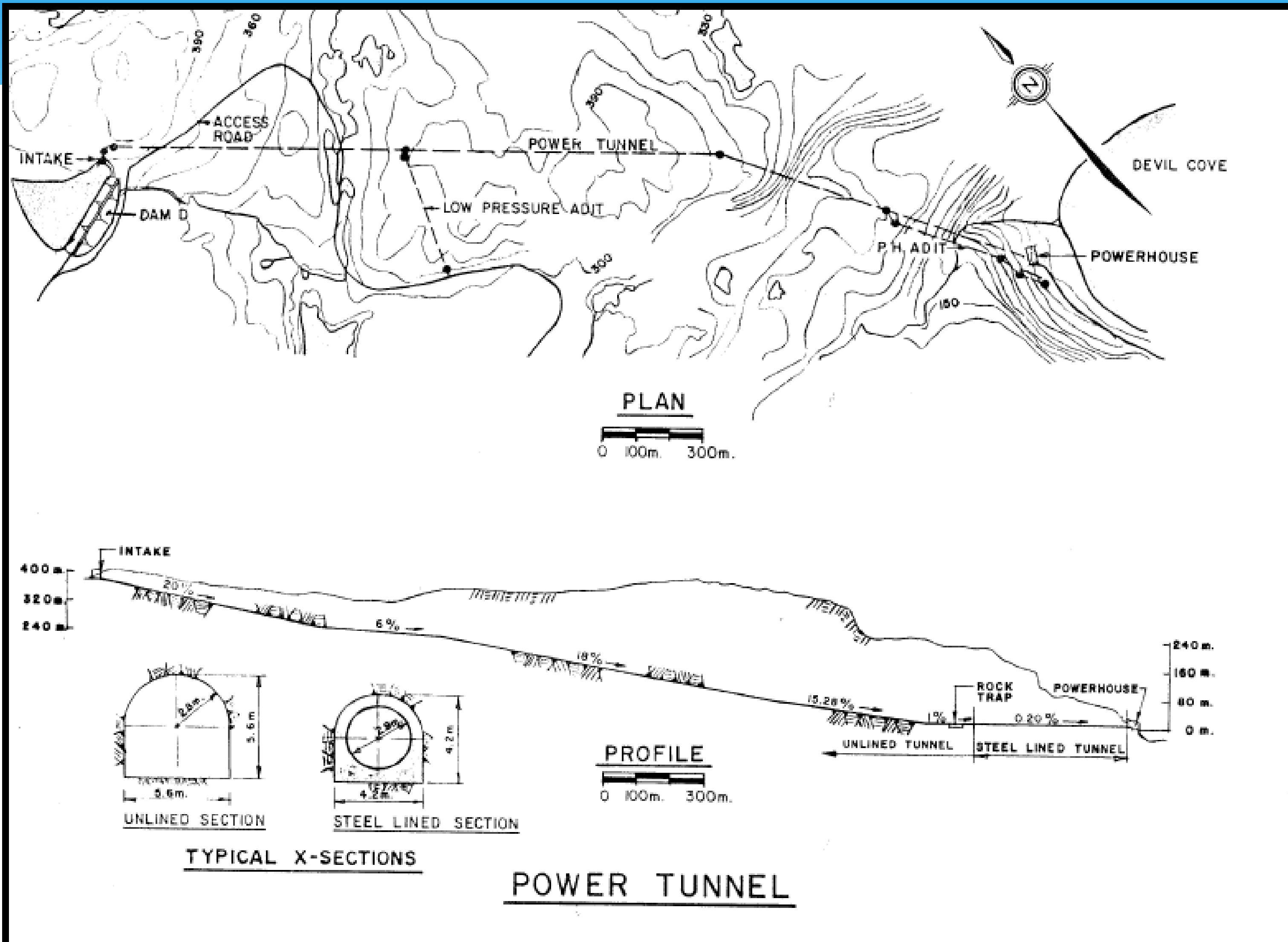
AFTER CONSTRUCTION CA. 1989

RIVER BEND



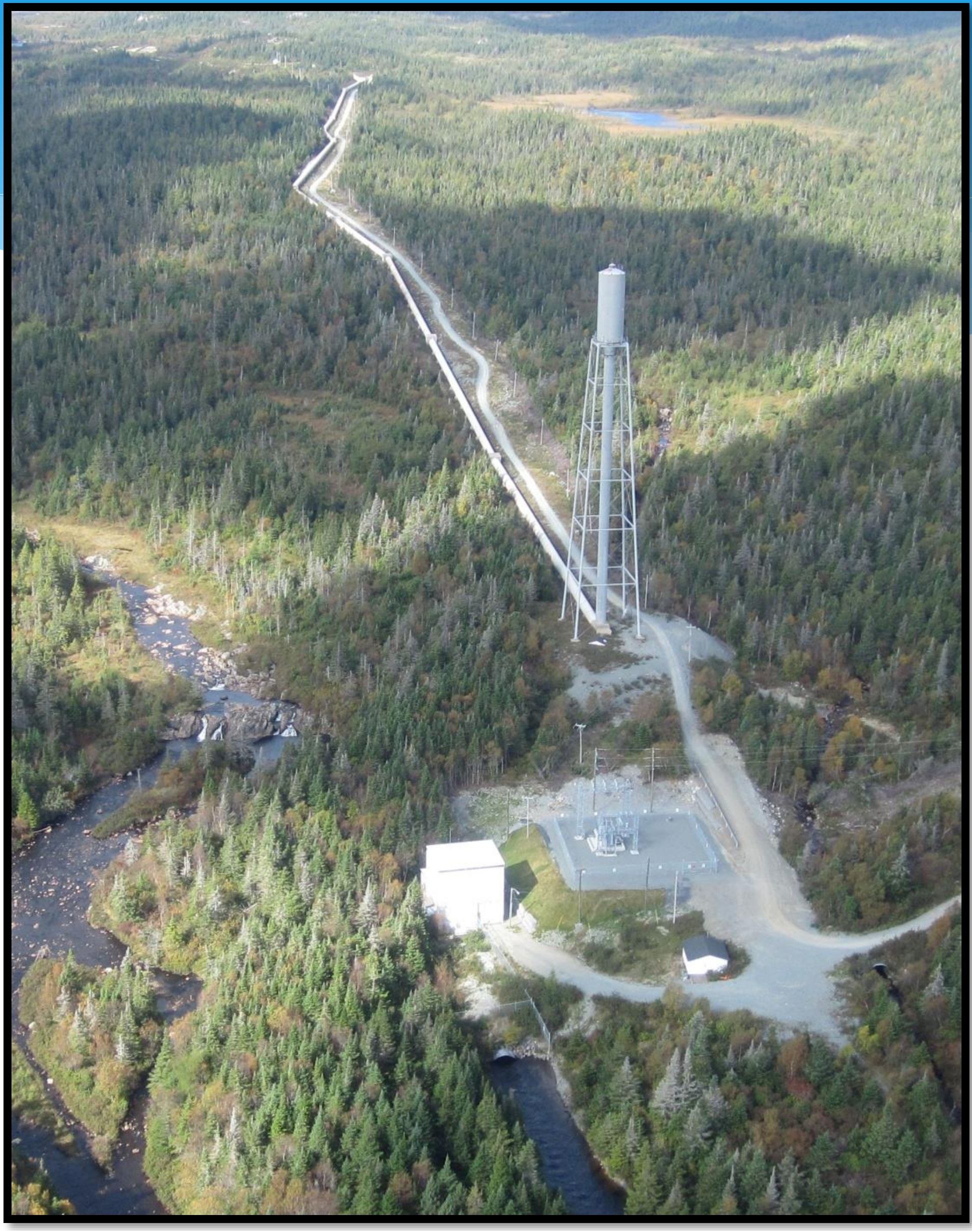
KALIGANDAKI I
300 MW

PLATEAU TO OCEAN



CAT ARM
127 MW

RAPIDS SITE

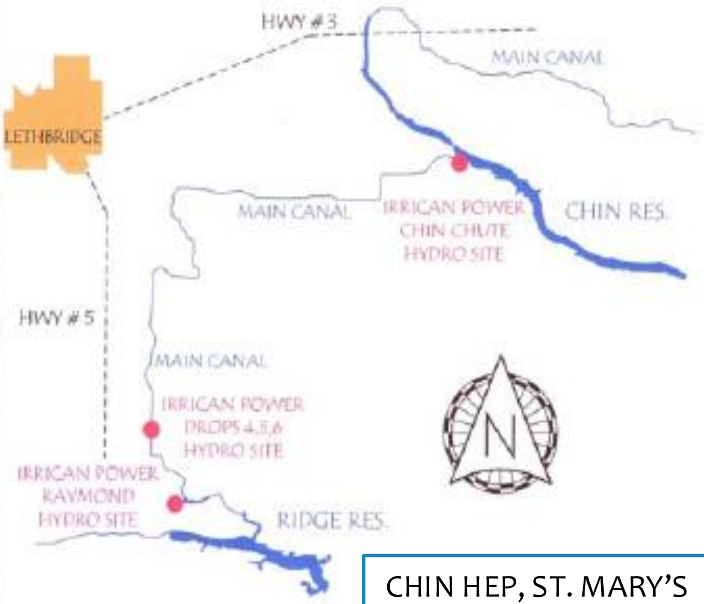


HORSECHOPS HEP: 8.1 MW

WATERFALLL
SITE:
HINDS LAKE
75 MW

MULTIPURPOSE: IRRIGATION & POWER

- A cast-in-place reinforced concrete tailrace structure to control tailwater elevations during low water levels in Chin Reservoir.
- A Synchronous Generator Nameplate Capacity 11.7MW. at 13.8 KV

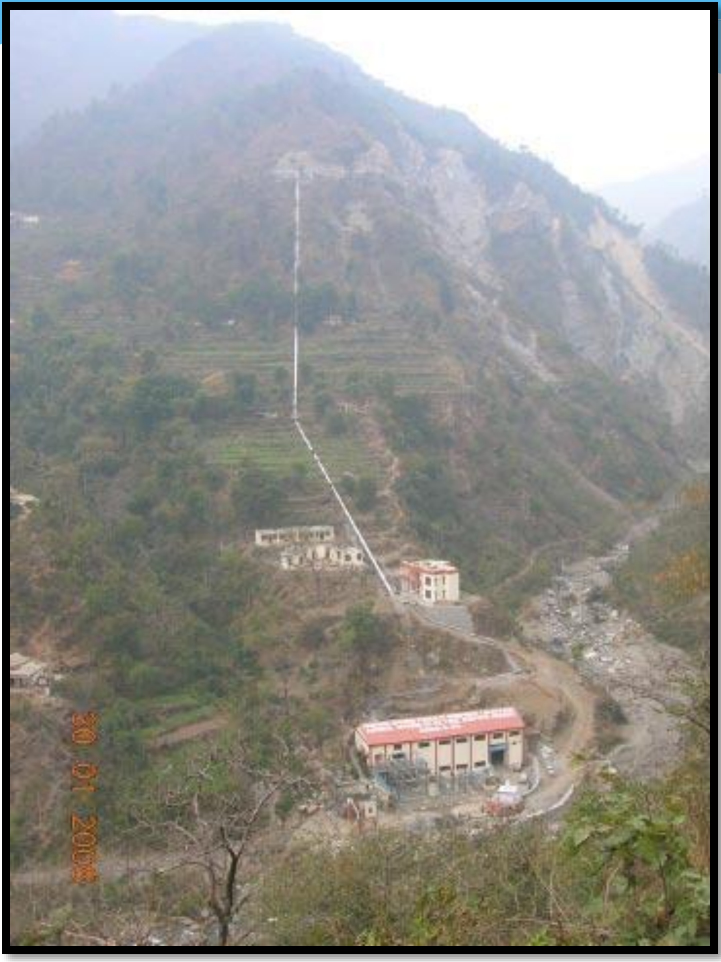


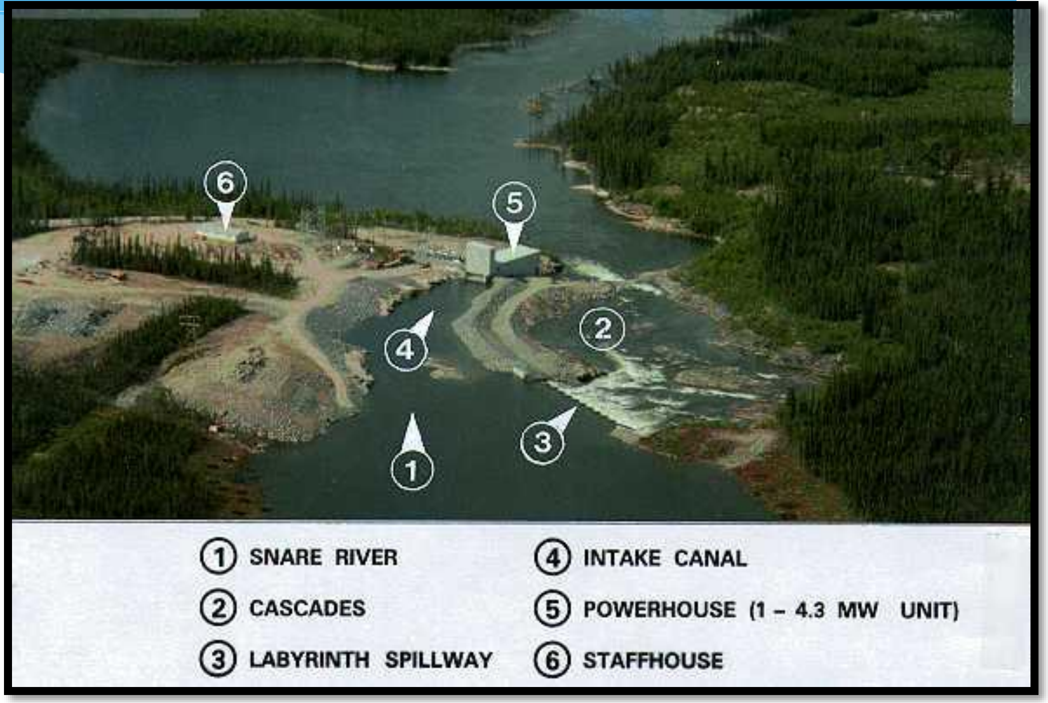
CHIN HEP, ST. MARY'S RIVER IRRIGATION DISTRICT, AB

MULTIPURPOSE: POWER & FLOOD CONTROL

TEMENGOR HEP
PERAK RIVER
MALAYSIA

HIGH HEAD VERSUS LOW HEAD





SNARE CASCADES: 4.3 MW, H = 9.1 m, Q = 55.3 m^3/s

MANDAL : 2X1.5 MW, H = 200 m, Q =1.8 m^3/s

LARGE VERSUS SMALL

TEHRI HEP: 1,000 MW

PORT UNION HEP: 400 kW

CLASSIFICATION OF RESERVOIR STORAGE

$$\text{STORAGE RATIO} = \frac{\text{LIVE STORAGE VOLUME}}{\text{MEAN ANNUAL FLOW VOL}}$$

CLASS	RATIO	EXAMPLE	STORAGE RATIO (%)	REMARKS
DAILY PONDAGE	~ 0.1%	Franquelin HEP	~ 0.1%	For 4 hours peaking, a longer peaking
				period will require more storage.
SMALL RESERVOIR	> 5% < 20%	Portland Creek	14.40%	Short term "temporary storage".
INTERMEDIATE	> 20% < 40%	Tarbela, Pakistan	25%	Seasonal storage
RESERVOIR		Snare Rapids, NWT	30%	Seasonal/annual
		Hinds Lake, NL	39%	Multi-year regulation
LARGE	> 40%	Cat Arm, NL	47%	Multi-year regulation
RESERVOIR		LG 2, Quebec	89%	Multi-year regulation
		Aswan, Egypt	300%	Multi-year regulation

COMPARISON WITH OTHER RENEWABLES

- Comparison of characteristics
- Comparison of technologies

CHARACTERISTICS OF RESOURCES

FEATURE	HYDRO	WIND	SOLAR
VARIABILITY	All natural energy sources are inherently variable and are dependent on weather, region and site factors.		
VARIABILITY	Hydrologic regime	Wind Regime	Solar Regime
VARIABILITY	Produce mainly secondary energy with little or no firm energy,		
PERSISTENCE	For perential rivers $\frac{Q\ 90\%}{Q\ mean}$ = 0.2 - 0.45	Nil	Nil
PREDICTABILITY	Days to seasonal	Few days to week	Days to seasonal

COMPARISON OF TECHNOLOGIES

FEATURE	UNIT	HYDRO	WIND	SOLAR
MATURITY (1)	-	Mature	Mature	Some way to go.
ROBUSTNESS	-	- usually unaffected by weather - vulnerable to water borne sediment - rotating equipment life: 15 to 30 years - dams and structures life: 50 to 100 years	- cut-in wind speed = 4m/s - cut-out wind speed = 25m/s - min operating temp: - 20 °C nominal - rotating equipment life: 20 years with replacement of gear boxes and bearings at 8 to 10 years - towers & foundation ~ 40 yrs	- potentially long life few moving parts - durability of materials will control longevity
AVAILABILITY READINESS	% time	95% to 98%	< 98% claimed when wind is available?	~ 100% when sunlight is available
ENERGY CAPTURE (2)	% of capacity	50% run-of-river 80% plus with long term storage	~ 30%	~ 13%
ECONOMICS	-	- water-to-wire equip't designs available - civil works unique at each site - subject to dis-economies of scale.	- developments use standardized equip't and tower designs - benefit from industry wide economies of scale. - unit costs improving	- developments use standardized equip't designs - benefit from industry wide economies of scale. - unit costs improving

CONTRIBTIONS TO GRID

- Provide "virtual storage"
- Rapid dispatch
- Frequency stabilization
- Dispersion of generation sources (sometimes).

PROVISION OF "VIRTUAL STORAGE"

In systems with large storage reservoirs water can be temporarily stored when production from wind generators is high and this stored water later used for energy production when winds are light.

RAPID DISPATCH

Hydro generators with storage can be dispatched rapidly. Typical loading times from start up are:

- Nuclear power: Days
- Coal fired thermal : 6 to 8 hours
- Gas turbine: ~ 15 minutes
- Diesel genset: ~ 15 minutes
- Hydro: 5 secs to 1 minute plus

FREQUENCY CONTROL

- Hydro generators react rapidly to system load changes to mitigate frequency swings
- Hydro generators contribute significant inertia to the grid.
- Can be operated as “synchronous condensers” to mitigate system load factor.

FREQUENCY STANDARDS

Remote plant supplying mining load:
Frequency limits 60 Hz +/- 3 Hz

German Norms:

- Frequency tolerance: 50Hz +/- 0.05Hz
- With step load change: 50Hz +/-0.20Hz

DISPERSION OF ENERGY SOURCES

System reliability is enhanced when hydro plants are dispersed across a regions. Diversity in flow patterns also provides benefits for run-of-river hydro.

Similar benefits are obtained from dispersed wind farm developments!

CHALLENGES TO HYDRO

- Large project footprint
- Environmental effects both positive and negative
- Socio-economic effects
- Regulatory regime.

FOOTPRINT

Hydro projects often have large footprints compared to other development projects. Environmental and socio-economic issues are proportionate to size.

SMALL FOOT PRINTS:

- Run-of-river
- Multi-purpose

LARGE FOOT PRINTS:

- Projects with large storage reservoirs, long transmission lines and access roads

ENVIRONMENTAL EFFECTS

- Inundation of shorelines
- Hydrothermal changes
- Biochemical
- Sedimentation
- Flow regime
- Impact on biota

SCOCIO-ECONOMIC

- Resettlement
- Impact on resource users
- Health
- Benefits: power and other uses, fisheries and recreation.

ENGINEER'S ROLE

Engineering Input:

- Simulation studies to characterize pre and post construction conditions.
- Design of mitigation options.
- Operation: design and implementation of operational plans and strategies.

BIOLOGIST'S ROLE

Biology Input:

- Assessment of ecological effects.
- Identification of mitigation opportunities and biological requirements / design criteria.
- Monitoring to verify "as designed" performance, detect changes and formulate corrective measures.

SOCIAL SCIENTIST'S ROLE

Socio-Economic:

- Assessment of project impacts on local populations both economic opportunities created and opportunities lost.
- Social effects and strategies to minimize adverse impacts.
- Strategies to maximize benefits.
- Evaluation of mitigation or compensation measures.

REGULATORY APPROVAL PROCESS

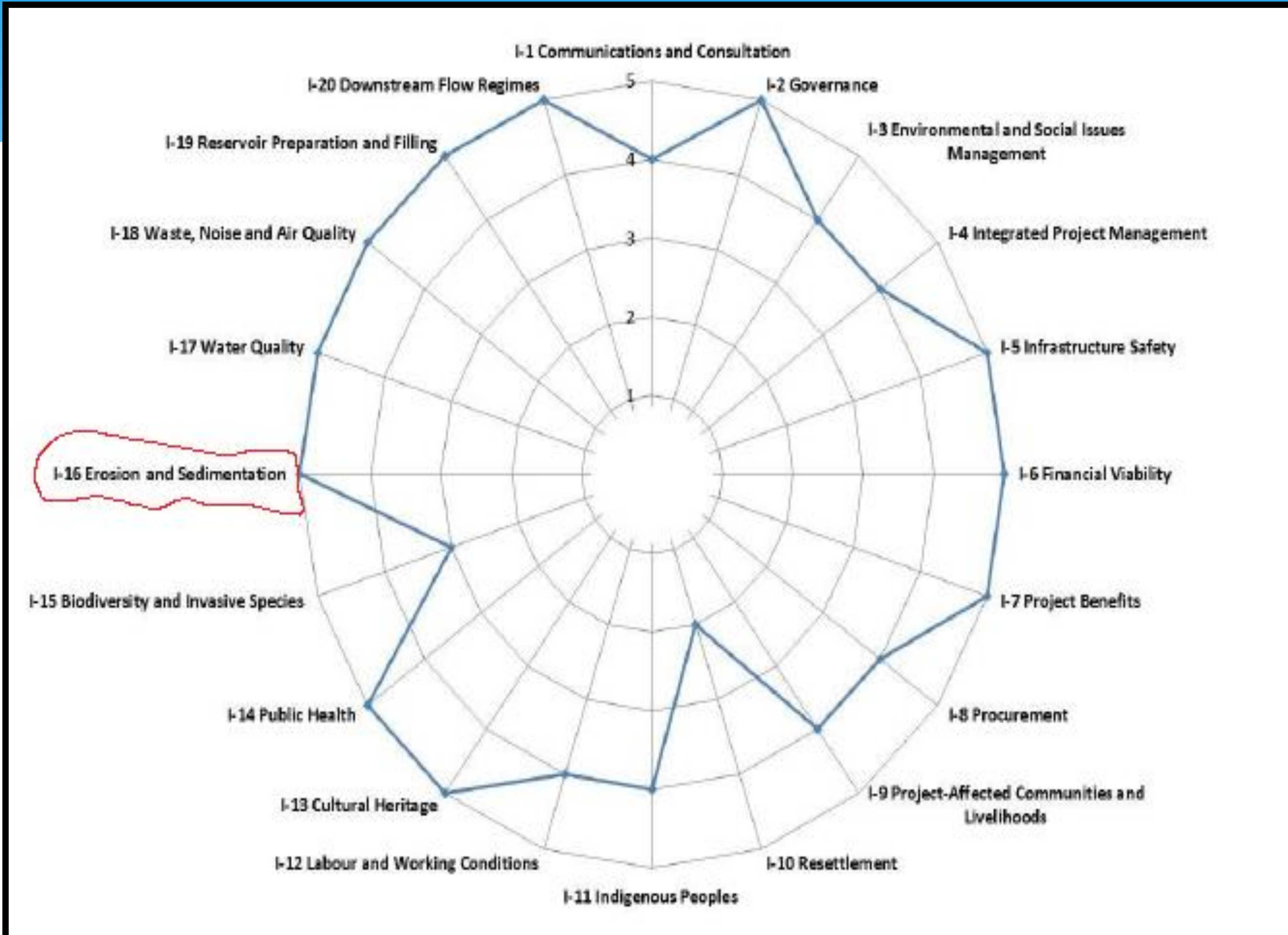
Convoluted and expensive.

IS HYDRO SUSTAINABLE?

Dictionary definition:

A method of harvesting or using a resource so that the resource is not depleted or permanently damaged.

JIRAU SPIDER DIAGRAM



CONCLUSION

1. The only factor affecting sustainability for hydro is reservoir sedimentation.
2. Most Canadian hydro projects are sustainable, because located on rivers transporting negligible silt loads.
3. Logically, hydro projects should be assessed, using two separate kinds of criteria:
   - *Sustainability and*
   - *Acceptability*

THE END

THANKS FOR YOUR ATTENTION.

ANY QUESTIONS?

Antoine’s Comments

WIND

approx. 4 m/s
usually 25 m/s
nominal -20ºC; with package -30ºC; very special package -40ºC

rotating: nominal 20 years but difficult conditions impose early replacement of gearboxes, bearings, after 8 or 10 years
foundations: minimal wear components; probably 40 years

Manufacturers usually claim 98% availability factors, below that, they have to pay penalties.

Betz limit dictates that only 59% (16/27) of the energy in the wind can be extracted
some turbine manufacturers claim a 50% efficiency, which is 84% of the energy that can be extracted.

A typical efficiency value for a rotor is 45%

The capacity factor for modern wind farms is about 35%.
Some reach as high as 45% others very low at 20%

FREQUENCY STANDARDS

Remote plant supplying mining load:

Frequency limits 60 Hz +/- 3 Hz

German Norms:

- Frequency tolerance: 50Hz +/- 0.05Hz
- Emergency overload:

  49.8 Hz, warning and mobilization of reserves.

  49.4 Hz, switching off selected customers.

  48.4 Hz, detaching customers having own supplies.

  47.6 Hz, disaggregation of grid into regional or local sub grids.