Innovante Water Solutions Pvt. Ltd. (IWSPL)

PHYSICAL AND MATHEMATICAL MODELLING PROJECTS

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Project 1: Upgradation for Improved Generation of Maniyar Small Hydro Project Sponsored by Carborundum Universal Ltd., Chennai, 2000.

Maniyar Small Hydro Project located near Patthanamthita was implemented by Carborundum Universal Ltd., of Murugappa Group,Chennai, with an installed capacity of 16 MW as a captive generation unit to support their industrial production plant near Kottayem in Kerala. The project comprised of a barrage across the Maniyar River along with intake structure, water conductor head race channel, forebay, power house and a tail race channel leading the flow back to the river. It was found that the project had been giving an output capacity of only 4 MW as against the projected 16 MW.

Detailed analytical, mathematical and physical scale modeeling studies had been investigated to identify the prime causes of the under-performance in the projected power output from the system. After careful synthesis of the aforementioned studies, the prime causes for under-performance could be narrowed to – excessive fluvial energy losses in the water conductor system due to design inadequacies, poor energy recovery in the draft tube, and elevated tail race flow level in the Maniyar River due to multiple obstructions in the downstream river channel.

Remedial solutions had been developed after two rounds of model testing to eliminate the undesired head losses in the system.

It had been very satisfying to record here that after executing the solutions in the prototype, the project maximum power output could be restored to almost 90% of the installed capacity i.e. 14 MW thereby raising it from 4 MW.

Project 2: Scale Model Experiments of Stepped Spillways for Rammam Stage - II Hydel Project Sponsored by West Bengal State Electricity Board (W.B.S.E.B), 2002.

The model testing for the above project has been conducted in the River Engineering Laboratory. The primary goal of the model studies relates to physical assessment of energy dissipation characteristics, flow behaviour, evaluation of aeration characteristics and cavitation risk through simulation of expected flow conditions.

Two stepped chute flume models made of transparent perspex sheets have been fabricated considering a model head of 2 m. The first flume is made for an inclination of 37^0 34’69’’ as a mono-slope stepped chute. The second flume is fabricated to represent a multi-slope stepped chute having gradient of 34^0 32’ in the beginning, followed by hill slopes of $52^0$14’ and 38^0 50’ for reproduction of the physical scenario existing at the site in the steepest portion of the hill slope closer to the Rammam river.

For faithful simulation of two-phase air-water flow and limiting the inherent scale effects to the minimum, the stepped chute models have been designed by adoption of geometrically similar scale ratio of 1:15 as recommended by international experts of repute on the basis of their first-hand experiences in Europe and America. The model prototype similitude has been reasonably attained by simultaneous fulfilment of the Froude, Reynolds and Weber similarity laws to ensure negligible influence of viscosity and surface tension effects, along with achievements of close similarity of aeration process and inertial forces in the model flows.

As regards the extent of energy dissipation, a comparison of results by different theoretical approaches with the model results has brought out that the method of Tatewar & Ingle yields very close values in reasonable conformity with the model in the present case for both mono-slope and multi-slope cases. In the light of the above finding, the hydraulic design details pertaining to energy dissipation characteristics for the adopted step geometry have been computed by Tatewar & Ingle method after duly accounting for its variance with the model results by an appropriate multiplying factor. Adopting the above approach, it could be estimated that macro-roughness offered by 447 no.s. of steps of the chute will be able to bring about dissipation of 476 m head leaving a residual energy of 8.64 m at the toe of the chute.

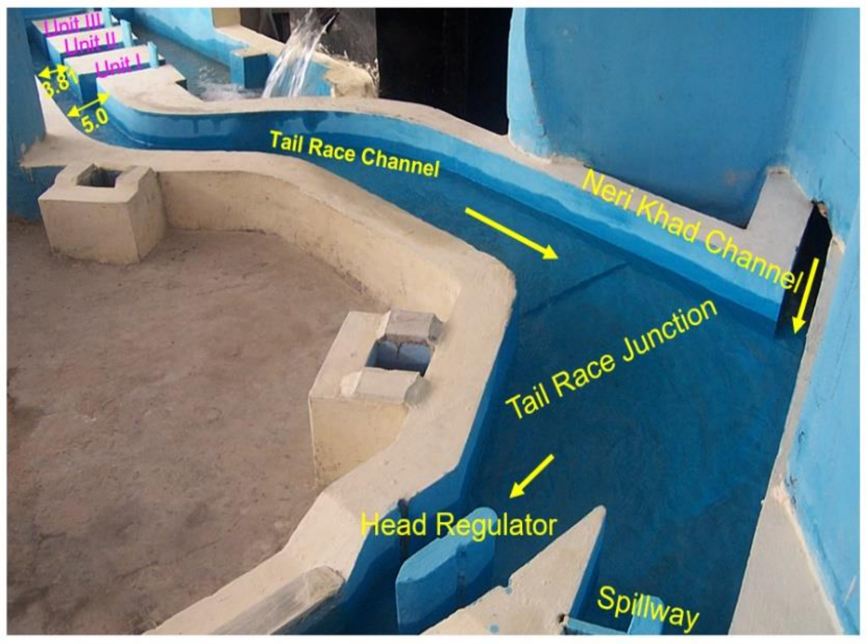
Assessment of aeration demand and cavitation risk has been made in the model-testing through measurements of piezometric pressures at vulnerable locations along the steps as well as aerated flow depth. The maximum observed value of negative pressure has been found to be of the order of 0.3 m which is quite well-within the tolerable limit. The magnitude of prevailing air concentration has ranged around 61% to 26 % and the Cavitation Number could be found to be 0.61 and 1.83 for multi-slope and mono-slope cases, both of which are reasonably well-within the safe limits prescribed by the Indian Standards and the literature. As already mentioned earlier, provision for aerators would be kept in the convex curve change-over zones to cater for the margin of safety.

Model setup without running condition

Notwithstanding the low residual energy value yielded by the exercise, a plunge-pool kind of terminal energy dissipation arrangement has been designed at the toe of the stepped chute spillways for a residual head of 30 m. This terminal dissipation arrangement of plunge pool will provide for the usual factor of safety in the hydraulic design.

Project 3: Hydraulic Model Study for Uhl Stage-III Hydro-Electric Project Sponsored by Himachal Pradesh State Electricity Board, (HPSEB) 2004.

The model study for the mixing of Bassi Power House tail water & water diverted from Nerikhad in a junction at the out fall of tail race and to optimize the efficacy of head regulator and spillway for passing the design discharge at appropriate level, was conducted on a separate model built to geometrically similar scale of 1:25. The model represented the tail race system from the four units up-to the tail race junction incorporating the channel from Nerikhad, the head regulator of power channel and the spillway. The head regulator consists of two bays of 2.4 m each separate by 1.0 m thick intermediate pier. The spillway also comprises of two bays of similar size and a pier. The crest of head regulator is kept 0.46 m higher than the spillway which is set at the bed elevation of the junction. A part of power channel was also constructed to simulate the effect of water levels in it on behaviour of tail race junction system.



Flow Pattern with Final Proposal – Tail Race Junction

Separate discharge measuring devices were installed for measuring the discharge of Bassi power house and the one diverted from Nerikhad. The velocity at various locations were noted with the help of ADV. The flow lines were observed by using suitable floats and the water levels with the pointer gauges having least count of 0.1 mm.

Details of Final Proposal– Collection Chamber

It was decided to study the flow behaviour in the tail race & the junction and to optimize the various elements of this reach extending from RD 0 to the head regulator first. The well guided and equalized flow will than be led in the power channel through the head regulator.

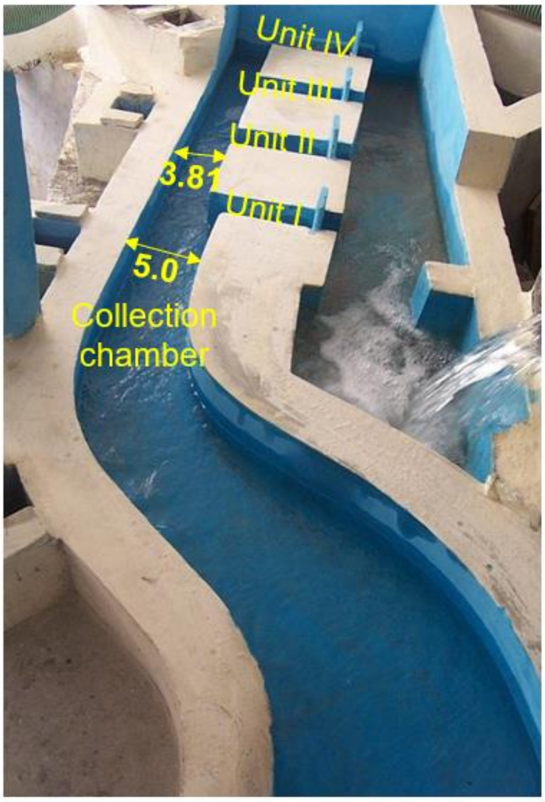
The model was run with the design discharge of Bassi Power House 21.6 cumec issuing from four units and 5.41 cumec discharge diverted from Nerikhad. The gates of head regulator were kept fully opened while the spillway was kept closed. The combined discharge of 27.01 cumec passed through the head regulator into the power channel.

Details of Final Proposal – Tail Race Channel

Flow Condition in the Tail Race

The flow from units IV to 1 of Bassi Power House mixed in 3.810 m wide tail race and entered the wider section of RD0. It was seen that the flow condition was not satisfactory. The water was more concentrated towards right leaving a backflow zone on left side. The uneven flow persisted at RD10 and RD22 also.

Flow Condition in the Tail Race Junction



Flow Pattern with Final Proposal – Tail Race Channel

After the tail race the flow reached the tail race junction but the condition did not improve. The water emerging from the right channel struck the front wall of the tail race junction. A dead zone was created in front of the divide wall at RD 52.

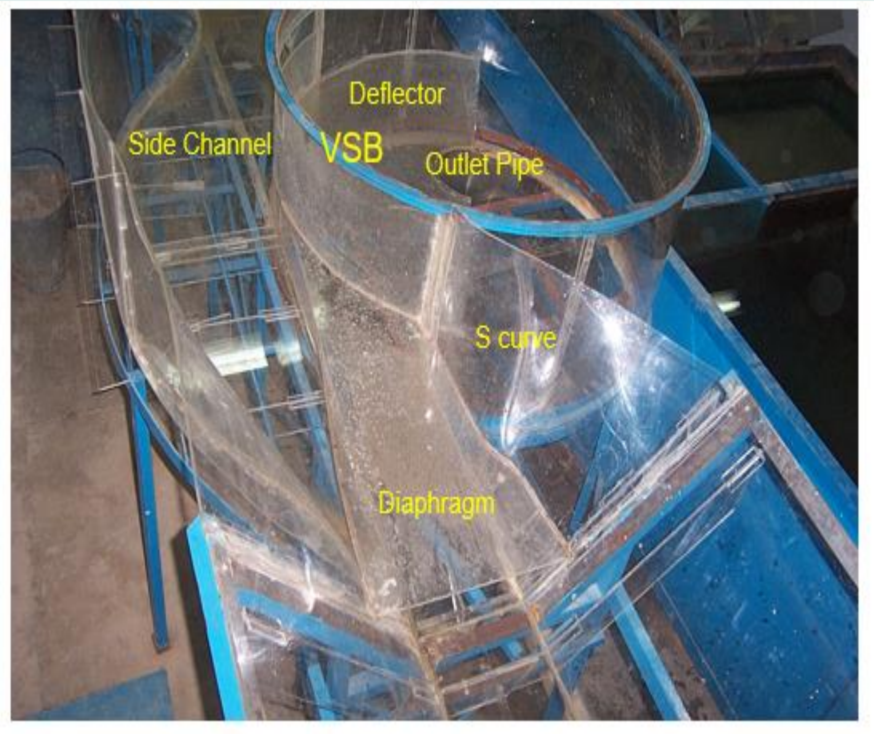
There was seen reverse flow at 0.6 D in front of left channel of tail race. Though the Nerikhad channel flow tried to activate the left side but it could not make the flow satisfactory. Low velocity zone still persisted at many places. The flow approached the head regulator in a relatively satisfactory way. Both the ways of head regulator were active. They did not draw equal discharge yet the wing wall on the spillway side was seen guiding the flow to the head regulator.

Project 4: Renovation and Design of Bottom Intake Structure and Desiliting Chamber for Jaldhaka Hydro Electric Project, Sponsored by West Bengal State Electricity Board (W.B.S.E.B), 2005.

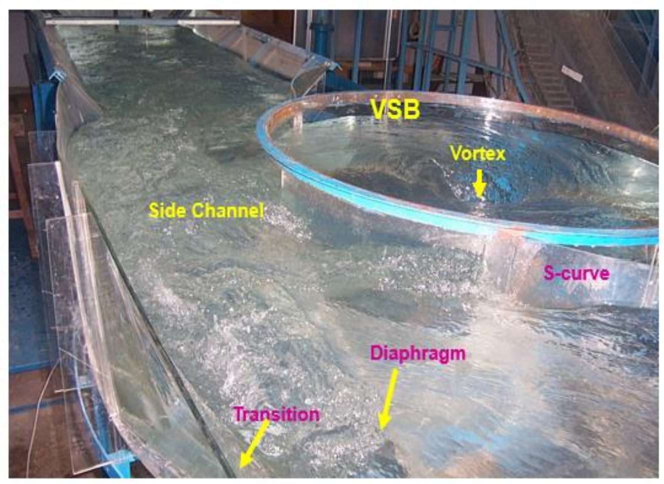
Layout of Model

The Member, (Hydro) WBSEB referred the aforesaid problem for evolving an appropriate desilting device for the Jaldhaka HEP. As a measure to reduce the problem of silting and choking of desilting device, the project authorities have diverted the waters of Bindu-Chu River during monsoon season exclusively for generation of power.

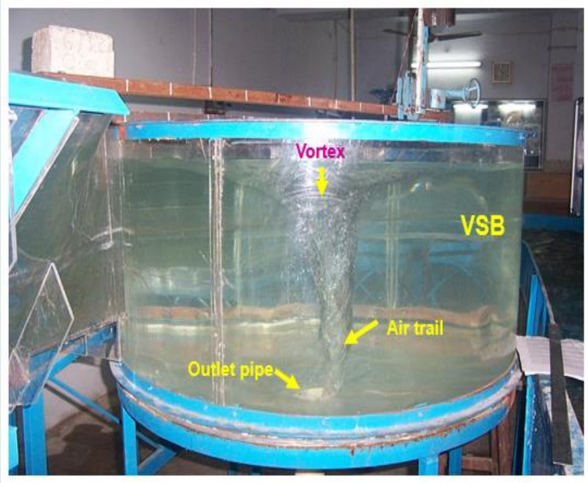
An intake across the Bindu-Chu River has been constructed for diverting the desired flow to the water conductor system through a power channel constructed over the barrage. During the monsoon season the sediment concentration of Bindu-Chu River is relatively less than that in Jaldhaka River. This proposal is conducive for providing necessary desilting device at a relatively less cost and efficient manner. For extraction of silt size ranging between 0.20 mm to 0.50 mm from the flow with due consideration for economical, efficient and water conserving alternative, vortex settling basin type sediment extractor is proposed to be adopted for Jaldhaka HEP.



Details of VSB



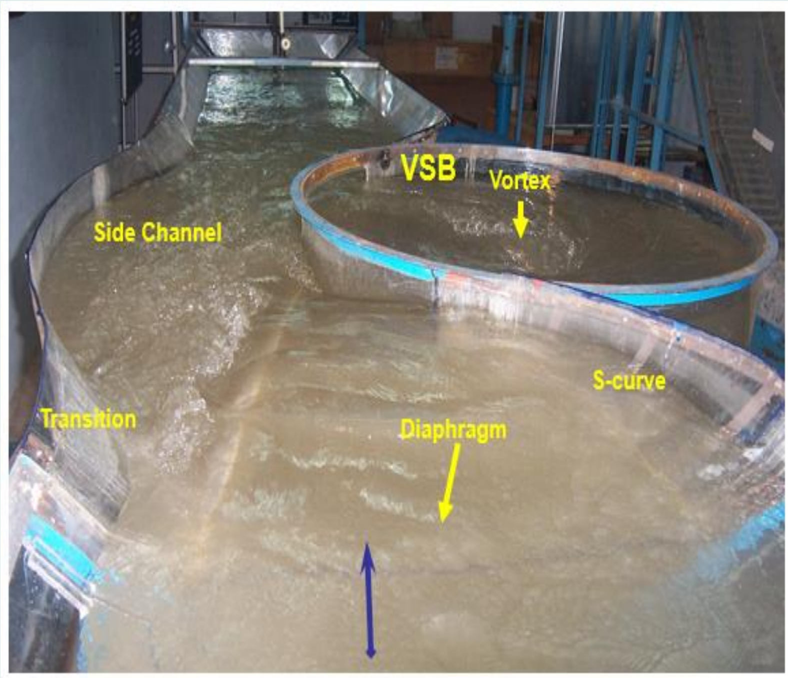
Flow condition at VSB Diaphragm height h/3



Flow in VSB Diaphragm height 0.6h

A geometrically similar model built to a scale of 1/10 was utilized to conduct the hydraulic studies in the River Engineering Laboratory. The discharge scale works out to 1: $(10)^{5/2}$ i.e. 1:316. The design discharge of 28.32 cumec for power house was thus determined as 89.6 lps (liters per second) for the model.

1. The physical model studies clearly established the efficacy of the VSB as a sediment removal device from the standpoint of sediment removal efficiency and savings in escape discharge, besides the advantage of its reduced space requirement and economy in construction.
2. The maximum sediment removal efficiency for the size of VSB as studied on physical model was found, of the order of 75% when diaphragm & deflector were provided at 0.6 h.



Flow Condition over Diaphragm & Side Channel Diaphragm Height 0.75 h

3. The flow in the side channel along the transitions adhered the left bank without any stagnation zones. Indicating that the layout is satisfactory.
4. The back rolling in side channel was eliminated by providing straight slopes.

Project 5: Hydraulic Model Studies with Laboratory Analysis of Field Data Samples for Sarda Sahayak Remodelling Project Sponsored by Tahal Consulting Engineers Ltd., Lucknow, 2006.

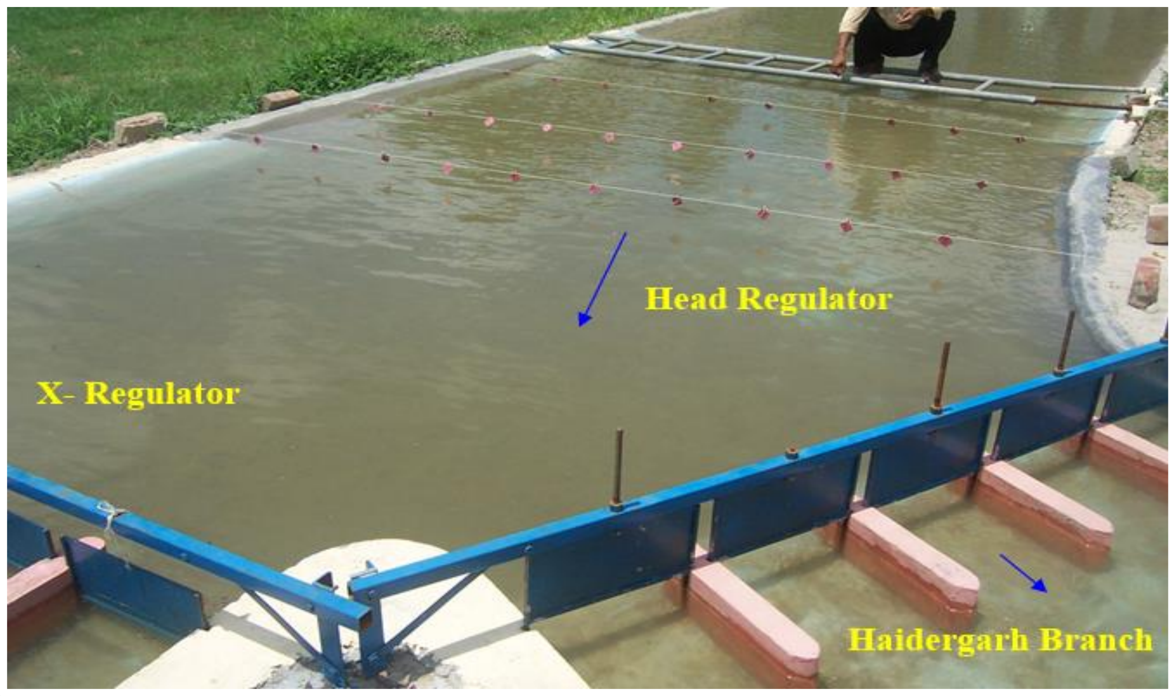
Divergence of Surface Flow Layers Away from Left Wing Wall Initial Proposal

Sarda Sahayak Feeder Channel takes off from right bank of Lower Sarda Barrage at Sarda Nagar, Dist. Lakhimpur Kheri. Dr. J. David Melamed, Team Leader and Mr. Y. N. Srivastava, Co-Team Leader of Tahal Consulting Engineers Ltd. held discussions with Prof. Dr. Nayan Sharma in his office on 19th April 2005 and requested to carry out studies for restructuring Haidergarh Branch Head Regulator of Sarda Sahayak Main Feeder for amelioration of the sedimentation and discharge carrying problems in its distribution system. M/s Tahal Consulting Engineers Ltd. Referred to conduct the Hydraulic model studies for Haidergarh branch Head Regulator.

A View of Layout of Model in Running Condition

The brief findings of the report is as follows:

1. The modified improved layout of the left wing wall



Observation of Surface Flow Lines Final Proposal Initial Proposal

has guided the flow in the model desirably well towards the Head Regulator and is therefore recommended for adoption at site. Benefits of modified lay-out of the upstream left wing wall as recommended herein are enumerated below:

(i) It will achieve desired flow equalization in the Head Regulator and activate the left side bays of Haidergarh Branch Head Regulator.

(ii) Existing heavy sedimentation along the left side of the Head Regulator and the branch downstream of the Head Regulator will be significantly reduced.

Sediment Deposition Pattern in Haidergarh Branch Final Proposal

(iii) Haidergarh Branch Head Regulator will pass its design discharge of 165.5m^3/s when Feeder Channel brings its design discharge of 357m^3/s by cross-regulator gate operation with a somewhat reduced afflux of 20cm.

Project 6: Physical Model Studies of the Interconnection Zone of Lodhoma and Rammam Tunnels of Rammam Hydel Project, Stage -II, Sponsored by West Bengal State Electricity Board (W.B.S.E.B.), 2007.

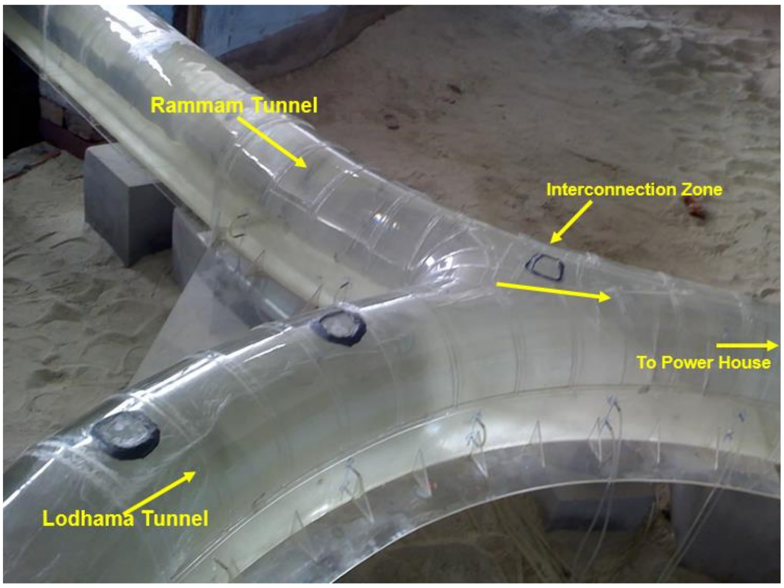
General View of the Running Model

1. The layout plan of interconnection arrangement as finalized vide the report titled "Hydraulic Analysis of flow in Lodhama Interconnecting Tunnel" January 2007, was found satisfactory to safely intermix the flows from Lodhama and Rammam tunnels without any adverse hydraulic pressure condition on the walls of existing Rammam tunnel.
2. The flow over the 450 inclined stepped chute having rise and tread 0.6 m each was

View of Interconnection Zone

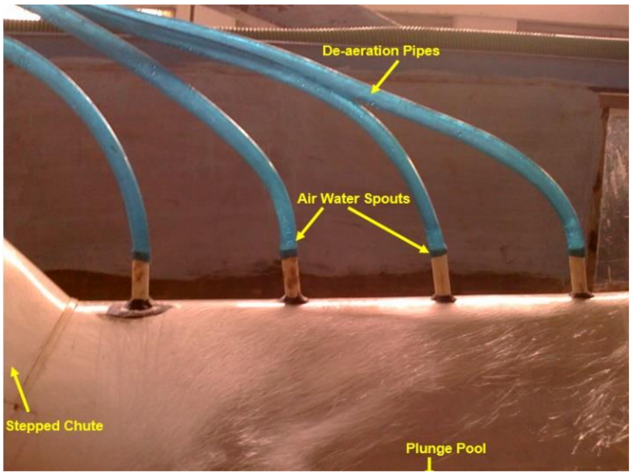
found appropriate to satisfactorily dissipate the excessive energy of the flow entering the plunge pool.

3. The 9 m long and 1.7 m deep plunge pool too was found adequate to dissipate the whole turbulence within it and allow a smooth flow to enter the interconnecting zone of the tunnels.

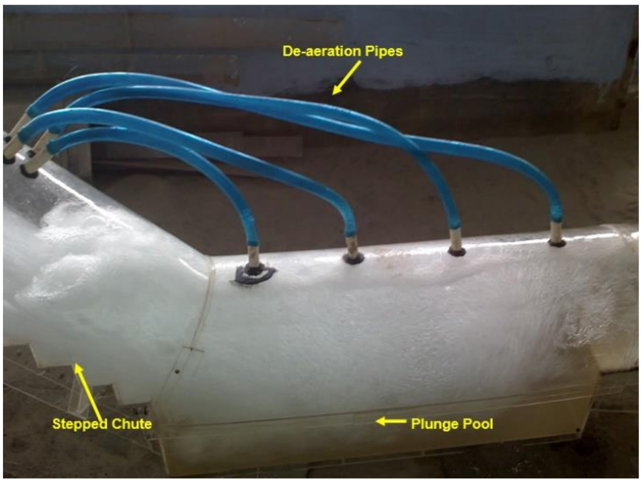


Smooth flow at the Interconnection Zone

4. Four numbers de-aeration pipes of 100 mm ϕ outgoing from the crown of the plunge pool have provided the outlet for release of air back into the stepped chute zone to an acceptable limit at the design discharge of 110 cusec passing through the Lodhama tunnel.
5. Though the four de-aeration pipes of 100 mm ϕ were also releasing the entrapped air at the emergent flow of 220cusec through Lodhama tunnel, some additional measures in the design of ribs are to be under taken. In order to enhance the capacity of tunnel support to withstand the internal excess pressure due to residual air, it should be ensured that steel struts and ribs provided in the support system are properly connected with each other.



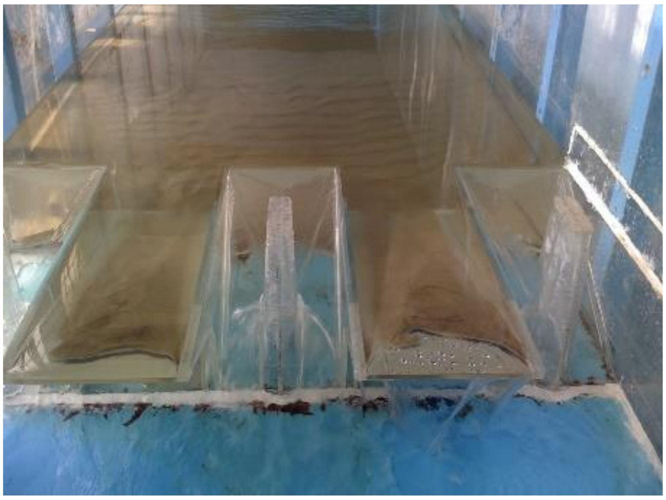
De-aeration pipes in action



De-aeration pipes

Project 7: Physical Model Studies for Modified Layout of Diversion Barrage for Sawra Kuddu Hydro Electric Project, Sponsored by Himachal Pradesh Power Corporation Ltd. (HPPCL), 2008.

Sawra Kuddu HEP with an installed capacity of 111 MW is located on Pabbar river in Himachal Pradesh. The flow diversion structure consists of four and three undersluices bays on left and right bank respectively each of 8 m width with 1.5 m thick intermediate piers. A 138 m long Piano Key Weir (P. K. Weir) / Labyrinth Weir is proposed in between the two sets of undersluices. Panel of Experts (POE) in their 2nd meeting held at Mandi proposed to conduct physical model studies on a flume to evolve suitable P. K. Weir elements and also on a comprehensive model to assess the 3D behaviour of the Sawra Kuddu Barrage system.



Flow over P. K. Weir with Sediment

Running view of P. K. Weir from U/S with under sluice gate closed at 2500 m3/s discharge

The findings of the model study is as follows

1. The hydraulic model study indicated that Piano Key Weir Model No. 6 having L/B = 4.91 was found most suitable based on discharge efficiency and sediment removal efficiency.
2. The study showed that about 47% of sediment approaching the Piano Key weir has been flushed out over the ramp when under sluice gates was kept closed.
3. Hydraulic efficiency of model no 6 raised by 1.25m was found better and sediment removal efficiency almost same order. Reservoir level was increased by 0.85m at inflow of 4000m^3/sec with Piano Key weir crest raised by 1.25m.
4. The sediment deposits in front of Piano Key weir have been flushed significantly when under sluice gates were opened to maintain MDDL at various incoming discharges varying from 2500 m^3/s to 1000 m^3/s.
5. The sediment got further washed out when under sluice gates have been operated under free-flow condition.

6. A tendency of self-activation of developing the left side channel leading to left under sluices and power intake has been observed in comprehensive model running under free flow condition.
7. The physical model studies indicated that with the observed hydro graph the stability of two channels reaching the two under sluices in MDDL condition could be established upto 100 m upstream of barrage axis.
8. The study indicated that very little fine sediment of the order of 0.4% deposited on the central raised platform at actual observed hydrograph maintaining MDDL.
9. When the model was run with 300 cumec discharge under free flow condition, having 1 m deposition on raised platform, it was found that the delta cleared in about 2 hours.

Under Sluices Gates Open Unequally

10. Various gates opening sequences are only locally effective in flushing the sediment under low discharges in MDDL condition. However at higher discharge the more opening of inner gates of under sluices near P. K. Weir was found more effective. Under free flow condition at 300 cumec discharge, more opening of left under sluice gate and very little opening of right side under sluice helped in accelerating the sediment flushing process.
11. A soil end sill of 3m height placed at 40m downstream from barrage axis was found suitable to push up the hydraulic jump on pucca floor
12. Model study indicated that CC blocks of appropriate size should be placed in the downstream of undersluices and P. K. weir upto 20m. However, for ensuring better protection of works as the tail water rating curve is synthetic only it is recommended that cast in situ CC blocks of size not less than 2m x 2m x 2m should be provided at least upto 30m.
13. Top layer of floor and CC blocks should be provided with abrasion resistant concrete so that the rolling action of boulders may be taken care off.

Running view of P. K. Weir from D/S with under sluice gate closed at 2500 m3/s discharge

Project 8: Hydraulic Model Study for Water Conductor System & Spillway of Thirot Hydro Electric Project, Himachal Pradesh State Electricity Board, 2010.

General View of Model

Thirot Hydro Electric Project located between El. 2700m to 2975m remains covered under a thick layer of snow for almost three months in a year, is a run of the river development on Thirot Nallah, a tributary of Chandra Bhaga River and joins the latter near Thirot village in Keylong Sub-Division of Lahoul Spiti Distt. in Himachal Pradesh.

General View of Model Alternative 1st

Sr. Executive Engineer Thirot Construction Division HPSEB, Pandoh, Mandi (H.P.) requested Prof. Dr. Nayan Sharma to conduct the physical model study on the following scope:

(i) Verifying above levels on a physical model as per Proposal – II.

(ii) Verifying, if siphon starts with pool level at mouth touching the level of 2965.24m.

(iii) Verifying, if siphonic action ceases with level of HGL at mouth of siphon falling to 2964.85m

Siphonic Spillway in Operation

Front View of Siphonic Spillway

(iv) Verifying that water level in forebay does not rise above EL 2965.46 when full discharge of 2.45 cumecs is being spilled from siphon spillway.

(v) If the above mentioned system does not work then the feasibility of using Proposal –I and likely level to be attained at forebay when full discharge is flowing through spillway.

View of Junction in Running Condition Alternative 1st

In order to examine the relative efficacy of both the proposals, the model was modified to incorporate the 1st alternative. Ten nos siphons were removed from the spillway and the crest of existing spillway was lowered to represent the chipping it down by 30cm uniformly. The crest level of modified spillway was thus provided at El. 2964.75. The length of crest was kept 300 m as per existing condition A 0.87m high, 0.5 m wide and 12m long weir was constructed at the junction of HRT and the adit.

Flow Pattern at Spillway Alternative 1st

The findings of the model study is given below

1) The maximum water level in the forebay reservoir in the event of load rejection at $2.45 m^3/sec$ in coming flow incorporating 1st alternative of existing spillway crest chipping by 30 cm and weir at the junction was observed at El. 2965.80.
2) As the first alternative is susceptible to least possibility of blockage etc., list annual repair & maintenance and easy to flush trash and floating debris is recommended to be adopted at site.

Project 9: Hydraulic study of Piano Key Weir for Lhasi Irrigation Project, Sponsored by Water Resources Department Rajasthan, 2010.

Lhasi irrigation project located on Lhasi River, a tributary of Chambal River in District Baran, Rajasthan is a multi purpose project. Live storage capacity is 19.82 MCM for irrigation and 8.48 MCM for power project. Maximum and routed flood discharges are estimated to be 1428 and 1115 cum respectively. The project envisages the construction of 2280 m long and 17.58 height earthen dam. In order to escape surplus water a 128 m wide Piano Key Weir having its crest at E.L. 345.6 is proposed to be constructed at site. Executive Engineer Water Resources Division-II, Chabra Distt. Baran has discussed the problem on 18th & 19th June, 2009. It was decided to conduct flume model study for a single model of Piano Key Weir as designed for Lhasi Irrigation project.

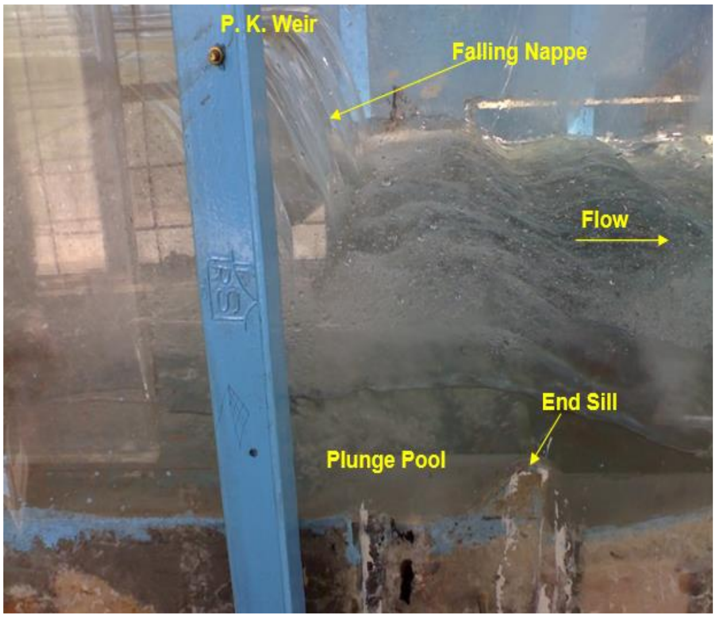
General View of Model

On running the model it was seen that plunge pool and downstream steps provided as energy dissipation device were not functioning properly. The flow was shooting over the steps leaving most of the energy un-dissipated. The length and depth of plunge was increased from 6.5 m to 8.5m & 0 to 1 m respectively.


Running view of Model at 354 m^3/ Sec discharge

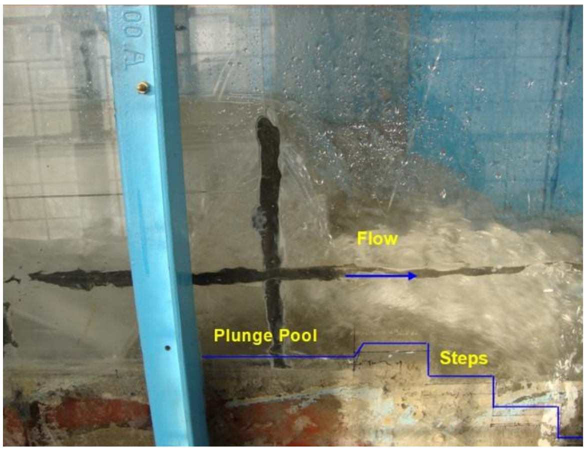
The flow behaviour over the energy devices was improved and shown in photos. However, it was not satisfactory. In the next trial, treads of steps were increased from 2m to 2.5 m. The flow behaviour at 1128 cumec discharge was observed satisfactory. There was enough aeration of flow and less residual energy passing in the downstream. The flow behaviour at 1128 cumec discharge with final dimension of plunge and tread of step is shown in photo. The model investigation indicated that the discharge passing over the Piano Key Weir was 4.3 times more than linear weir at lower head over the crest of the weir and 2.5 times more at higher head over the crest of the weir.

Running view of Model at 1128 m3/ Sec discharge



Flow Pattern Downstream of P. K. Weir at 1000m^3/s Discharge Initial Proposal 23 m Long Plunge Pool Bed El.1405.75

The model study also indicated that the plunge pool of 8.5 length and 1 m depth followed by steps with 2.5 m tread and 1 rise m was found sufficient to dissipate the surplus energy passing over the Piano Key Weir.



Running view of flow behaviour of energy dissipation at 1128 cumec

Project 10: Physical Model Studies for De-sanding Arrangement of Sawra Kuddu Hydro Electric Project, Sponsored by Himachal Pradesh Power Corporation Ltd. (HPPCL), 2011.

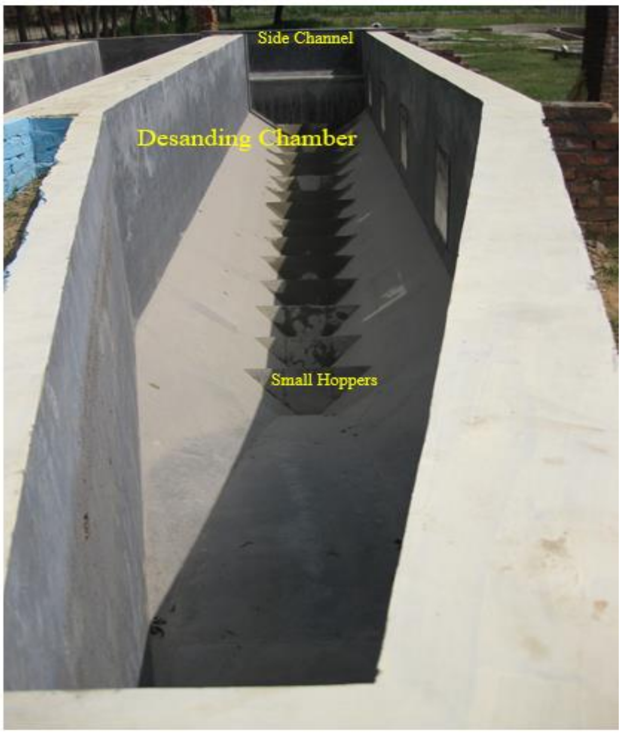
Sawra Kuddu Hydro Electric Project envisages construction of a P. K. Weir along with under sluices on both the sides of the weir across river Pubber in Himachal Pradesh. The power intake on left bank is designed to draw 83.1 m^3/s discharge which will pass through a desanding system. The desanding system consists of three surface desanding chambers each 94.0 m long, 17.6 m wide and 12.6m deep up to hopper level for excluding sediment partials down to 0.25 mm. Water from intake shall be carried through three independent RCC box type feeder conduits each 3m x 3m in size. The sediment laden water shall enter the flushing conducts underneath through bottom opening spaced at specific distance.

An Overview of the De-sanding Chamber Physical Model

Another View of De-sanding Chamber Physical Model

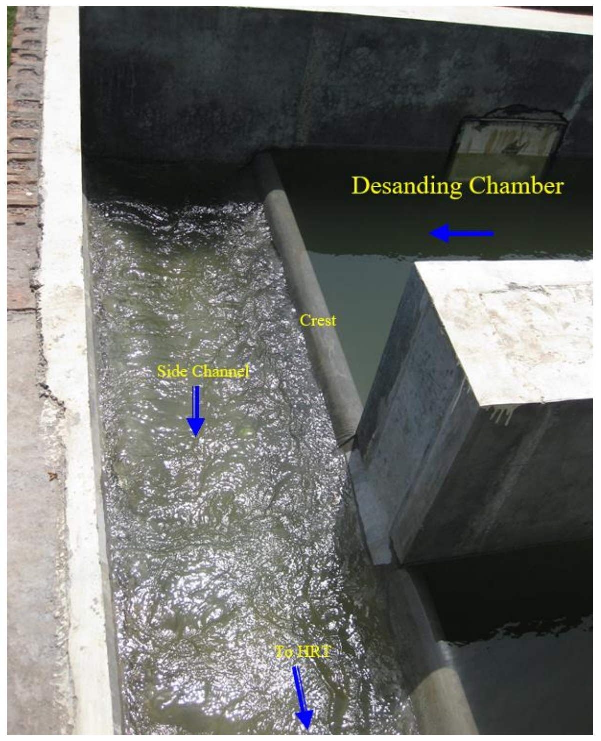
This water shall be further discharged in to Pubber River through 1.3 m dia 3 nos steel pipes laid in mild reverse slope. Clear water shall be collected in trapezoidal side channel located at downstream end of chambers and carried further to the HRT through HRT intake gate.

The physical model study indicated that



Small Hoppers in the Desanding Chamber

1) Size and layout of feeder conduits and length of transition portion were found adequate and sufficient to distribute the flow and sediment satisfactorily in Desanding Chamber.
2) The overall efficiency of the system was found around 75% however the efficiency for particles > 0.25 mm was of the order of 84%. The size of chamber and the sediment flushing efficiency of the system is therefore adequate.
3) Estimated flushing discharge passed through the flushing duct and no opening was found choked. It indicated that the size and spacing of the openings are in order.



View of Flow Condition in the Side Channel

4) The velocity in flushing duct was observed around 3.8 m/s which is sufficient to move the particles of size 20mm as per Shields' criterion.
5) Size and layout of flushing pipes was found adequate and proper.
6) Water surface profile in the side channel indicated that the water level in operating chamber during repair in the other chamber should not be raised above El. 1411 to ensure that there is no overflow into the empty chamber.
7) No vortex formed at HRT intake under any operating condition.
8) Modifications of slope in transition zone, extension of small hoppers and rounding of the sharp corners of the side channel, evolved by physical model study are to be implemented as discussed in model investigations.


Sediment Laden Water Flushing out in River

Project 11: Physical Model Studies for Surge Shaft & Tail Race System of Sawra Kuddu Hydro Electric Project, Sponsored by Himachal Pradesh Power Corporation Ltd. (HPPCL), Shimla, 2011

General View of the Surge Shaft and Tail Race Model

A physical model of water conductor system representing reservoir, HRT, head race surge tank, pressure shaft, manifold, draft tube gate shafts, tail race surge tank, TRT and outfall was constructed keeping $L_r = 1/300$, $Z_r = 1/60$ and $D_r = 1/32$ at outdoor River Engineering Lab. The findings of the model study is given below

1) Head Race Surge Tank having finished internal dia of 14 m and top at El 1449.5 with orifice dia of 1.65 m was found adequate and sufficient. The maximum and minimum surge levels in the worst operating conditions were noted at El 1446 and 1376 respectively.

Another View of the Surge Shaft and Tail Race Model

2) Physical model study indicated that the minimum water level in tail surge tank will be observed when the outlet structure in the river Pabbar does not have sufficient water level to submerge it.
3) The open to atmosphere tail race surge tank having internal dia 8m and orifice dia 2 m, located at RD 300 was found adequate to restrict the minimum water level in it at El 1215 for the operation 110-0-67 which is sufficient to avoid the air entrainment into the TRT, when outlet structure was running free.

Free Flow Condition at Tail Race Out Fall

4) The physical model study indicated that provision of expansion gallery (s) is not required because the minimum water level for the operation 110-0-67 in the tail race surge tank having orifice dia 2 m was observed at EL. 1215 which is sufficient to avoid the air entrainment into the TRT, when outlet structure was running free.
5) The maximum water level in the TR surge tank and TRT gate shaft were observed at El 1221.5 and EL 1222.5 respectively in full load acceptance at the highest downstream tail water level.

Tail Race Surge Tank

6) To release the air bubbles found in the draft tube in 3u-quick shut down operation at the lowest downstream tail water level, it is recommended that on next load acceptance the unit near to the tail race surge shaft should be started first.

Project 12: Physical Model Study for RCC Gandak Bridge in Bishunpur Panchayat of Gopalganj District of Bihar, Sponsored by Bihar Rajya Pul Nirman Nigam Ltd., Patna, 2011.

Side View of the model

River Gandak is a major left bank tributary of river the Ganga flowing through Bihar. This river is mountain fed and originated from the foothills of Himalayas entering Bihar at Valmikinagar and finally merging into the River Ganga at Hazipur in the district of Vaishali, Bihar. The distance between Valmikinagar and confluence with Ganga is 258 KM. The flow in the river is regulated by the barrage constructed across the river at Valmikinagar. But during the High Flood season, the peak discharge is so much that, the regulation of its flow at the Valmikinagar Barrage goes to a halt and during peak flood season all the gates of the barrage are opened which causes the rush of flood water and consequently nearly 14 km wide area along the river gets submerged. The river has got no defined bank near the bridge site which necessitated the proper study of the physical model to know about the expected future pattern of flow around the bridge location.

Downstream view of the model

In the model study of the river for the proposed site it has been found that the river has got a very high meandering tendency around the bridge site. The satellite images also indicates that the river has been oscillating between the two bunds, the Yadavpur bund in Gopalganj and the Champaran bund near

Mangalpur village. It has been observed that the river has tendency to flow in two parts near the bridge site. On Gopalganj side Basi river mixing with 2nd channel of Gandak river carries 60% flow of entire Gandak river. In model study special attention was given to control the Basi mixed Gandak on Gopalganj side by providing a larger length of Guide Bund.

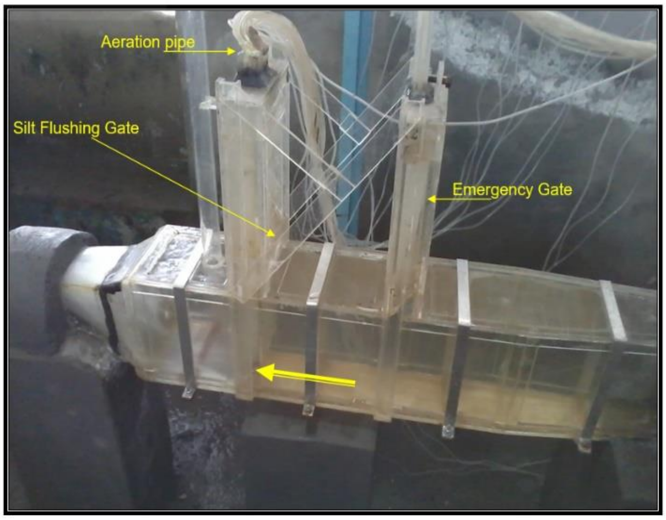
Conclusion:

Full-view of the Comprehensive Physical Model

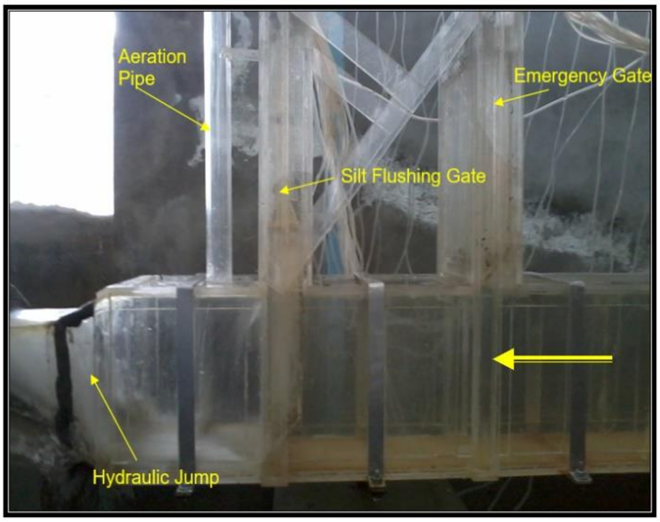
1) The river on the Gopalganj side to be tamed by further increasing the length of Guide Bund by 200 m on U/S side. Increase in the length of guide bund on downstream side at Gopalganj end is not advisable as it will completely block the river flow; hence it is not technically feasible.
2) The shape of the guide bund is finalized with a little tilt away from Gopalganj (downstream side) as shown in plan in order to put the river further away from Gopalganj and to avoid the rush of the flood water towards Gopalganj during flood season. The total length of Guide Bund on Gopalganj side would be 2489 m and the length of Guide Bund on Bettiah side would be 1518 m. The length of Guide Bund on Bettiah side is decreased to cause the minimum obstruction to the flow because part of the approach road connecting guide bund on Bettiah side is almost parallel to the flow and functions like a guide bund. The countryside of Guide Bund should also be protected by giving single layer of boulder pitching on slope with only key apron.
3) The scours caused by the water during model test were noted and accordingly it has been finalized that in u/s 33.5 m long 0.75 m thick apron in upstream curved portion of Guide Bund and 23.5 m long 0.75 m thick d/s portion of Guide Bund conforming to IS code should be provided. The length of the bridge should be increased by 420 m to accommodate the part of the Gandak with Basi river on Gopalganj side. This has been already suggested during the mathematical modeling test of this project. During the physical model run the flow pattern was found to be well convergent between the two guide Bunds for both High flood and for normal flood.

Project 13: Model Study for Silt Flushing Intake Gate of Sawra Kuddu HEP, Sponsored by Director Project, Aarti Infra Project Pvt. Ltd., 2012.

The findings of the above physical model study is given below

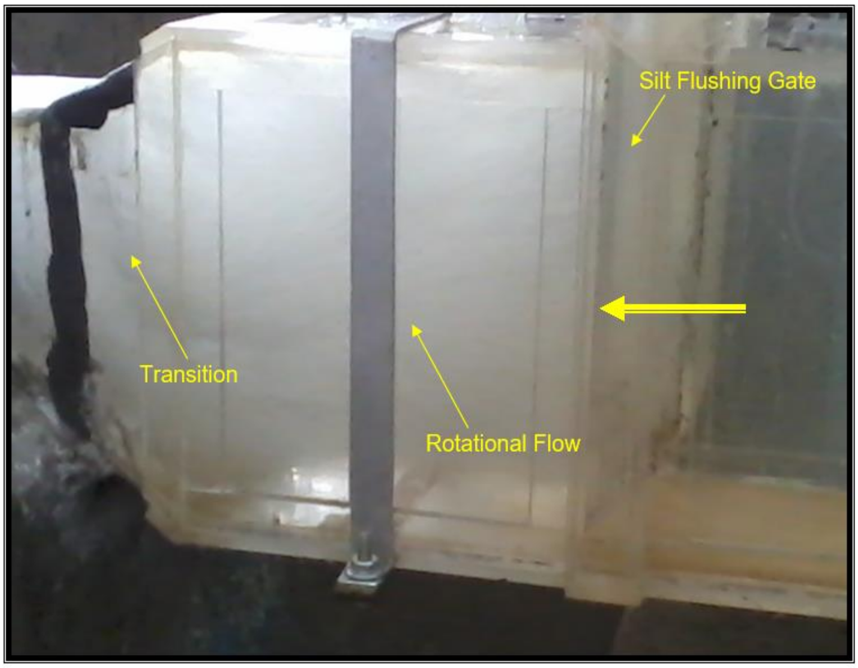


General View of the Model

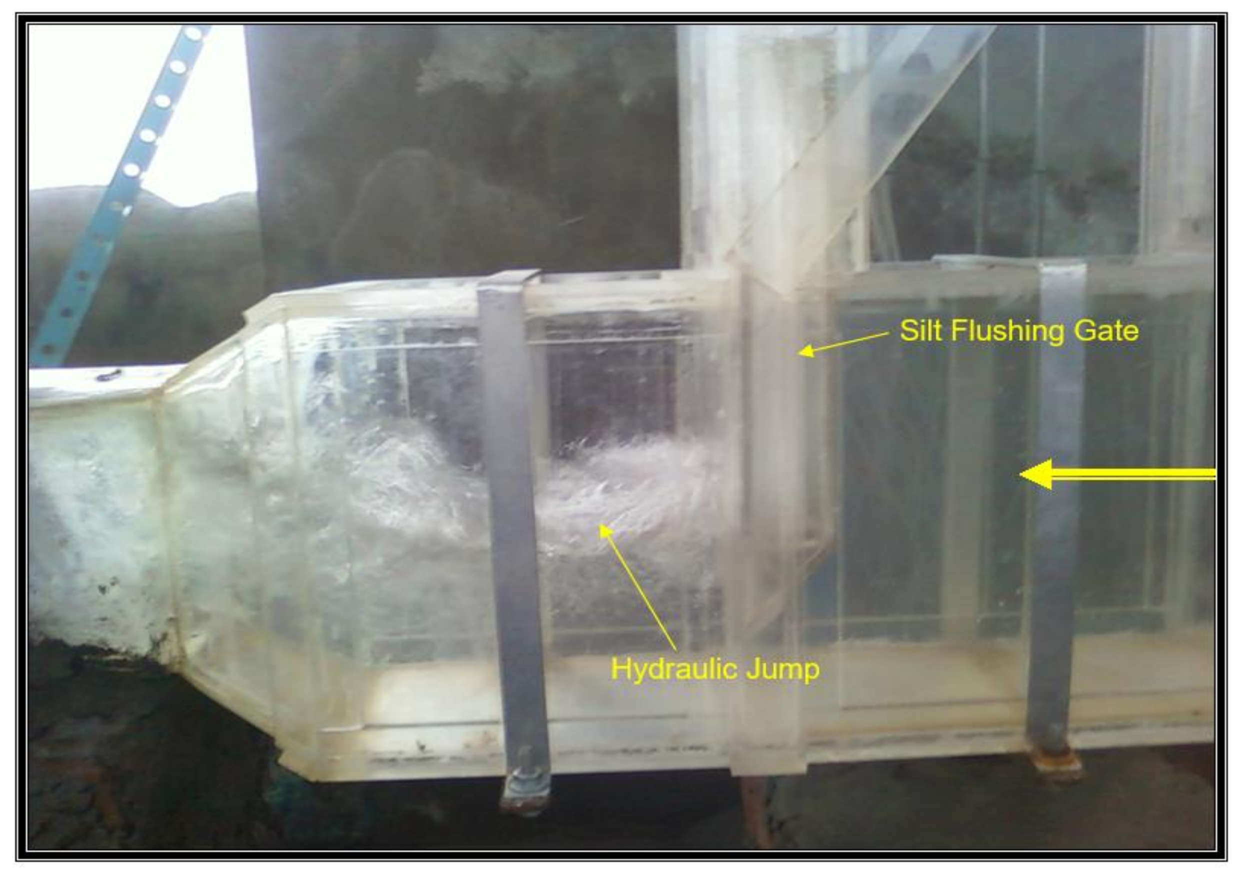


Flow Condition at 8% Gate Opening - Free Flow Unaerated

1) The physical model study indicated that the flow through the flushing gate was quite calm and smooth when the discharge was passing though the reverse sloping flushing pipe.
2) The flow under the gate in rarely expected free flow condition, too was found in accordance with the normal behaviour of such structures. No adverse flow characteristic was observed.
3) Model studies indicated that there was no negative pressure on 45^0 sloping lip of the flushing gate. No excessive negative pressure wa s observed at any location. The design sloping lip at 45^0 was therefore found hydraulically satisfactory and adequate.



Flow Condition at 8% Gate Opening - Free Flow Aerated



Flow Condition 25% Gate Opening Unaerated

4) An aeration pipe of dia 0.25 m provided at 0.7m downstream of flushing gate groove centrally was found adequate and sufficient to aerate the flow escaping under the gate.
5) Maximum negative pressure of the order of 2.1 m water head was observed on the physical model under free flow condition. However, in aerated condition the maximum negative pressure was of the order of 1 m. For design purpose a maximum 5 m negative pressure may take care of required factor of safety also.
6) As the maximum negative pressure observed on the physical model is well within the permissible limit, no risk of cavitations was indicated by model study.
7) The physical model study indicated that the sediment laden flow passed safely through the flushing gate. No undue deposition of sediment was seen at the gate sill.

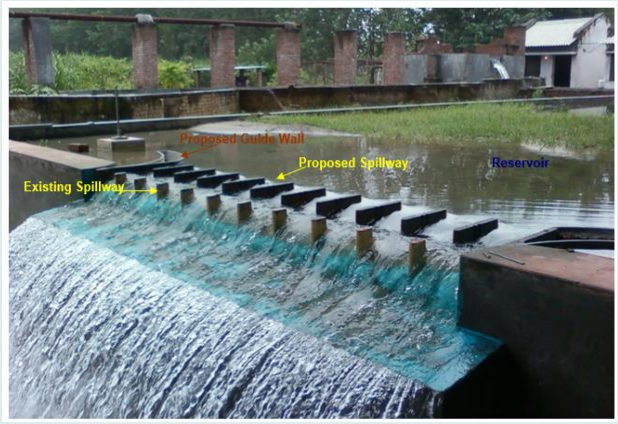
Project 14: Hydraulic model studies for Dam spillways of Chandan Reservoir Sponsored by APRL, Ranchi, 2012.

M/S Abhijeet Project Ltd. referred the physical model study of Chandan spillway to IIT Roorkee for the following scope of work

General View of the Model with Existing

a) To fabricate and conduct of physical model study of existing spillway to assess the probable discharging capacity whether it will be 1, 10,000 cusecs or 1,60,000 cusecs or in between
b) To fabricate and conduct of physical model study of proposed gated spillway in upstream for flow discharging capacity and if required introduce suitable modification in the spillway crest level of proposed gated spillway for passage of desired discharge.

Flow Condition at 1,10,000 Cusec over the Existing Spillway

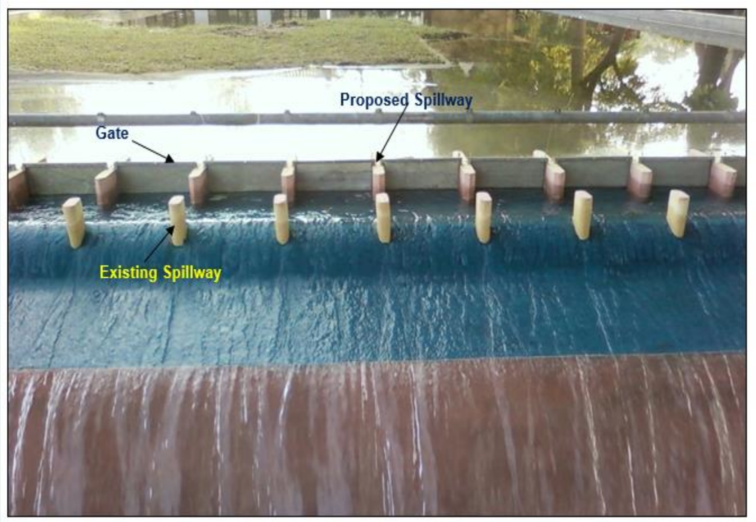


Flow Condition at 1,10,000 Cusec over Twin Spillways (Crest of Proposed Spillway at El 152.44 m)

During discussion with the representatives of the sponsor, various other points were raised and the following were agreed to be investigated.

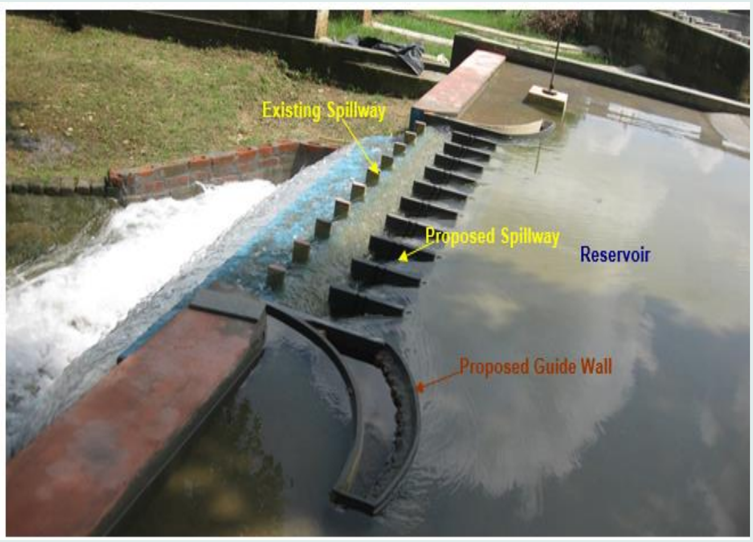
1) The maximum water level of 157.01 m should remain in the both cases
2) The outflow discharge has to be established through existing spillway at MWL of 157.01 m and has to be confirmed to be 1,10,000 cusec.
3) The same outflow discharge 1,10,000 cusec be kept constant of the proposed gated spillway.
4) The maximum water level with the proposed gated spillway is to be in close proximity of 157.01m.

The behaviour of structure of the proposed and existing spillway has to be studied for their hydraulic performance like formation of eddies, vortex etc.



Front View of Gated Flow Condtion of Twin Spillways (Crest of Proposed Spillway at 151.70 m)

A physical model comprising 1 Km upstream reach of Chandan reservoir, existing spillway, the guide wall and downstream chute was constructed at outdoor river engineering lab to a geometrical similar scale of 1/50. The discharge scale works out to 1/17,678. The spillway profile, piers, guide walls, downstream chute and upstream river portion in the vicinity of spillway was constructed and laid in cement mortar. Adequate baffle walls were provided to ensure smooth entry of the flow approaching the spillway. The discharge was measured over a V notch installed at the head of the model. The water levels were read by pointer gauges having least count of 0.01 cm.



Side View of flow condition at 1,10,000 Cusec over Twin Spillways (Crest of Proposed Spillway at El 152.44 m)

A comprehensive physical model of Chandan Dam spillway was constructed by Prof. Dr. Nayan Sharma to investigate the discharging capacity of ungated existing spillway at maximum reservoir water level of 157.01m and to optimize the crest EL of proposed gated spillway upstream of existing one so that the design flood may be passed through the twin spillways thus formed with a little afflux. The model studies indicated that at MWL of 157.01 m a discharge of 3114.82 m^3/s (1,10,000 cusec) passed over the existing ungated spillway. Further it was found that the above discharge escaped over the twin spillways at the MWL of 157.02m when the crest of newly proposed spillway was kept at EL 151.70 m. The flow behaviour under gated condition of proposed spillway at this crest level keeping 1 m gate opening was also found satisfactory and acceptable. The crest level of proposed gated spillway at EL 151.70 is therefore recommended.

Project 15: Comprehensive and Flume Hydraulic Model Studies for Chhatru Hydroelectric Project (126 MW) in Chenab River Basin, Sponsored by DCM Shriram Infrastructure Ltd. 2013.

General View of Comprehensive and Flume Model

Chhatru Hydroelectric project is proposed on river Chandra, a major tributary of river Chenab in the head-reach, in Lahaul and Spiti district of Himachal Pradesh. The Project is planned as a run-of-the-river scheme with provision for diurnal peaking storage. The project area is located near Chhatru, a seasonal tourist camp on Gramphu-Kaza road about 17 km from Gramphu, which is located on Manali-Rohtang-Keylong highway (NH-21) at a distance of about 23 km from Rohtang.

The Chief Executive officer, DCM Shriram Infrastructure Limited entrusted the physical model study of the project covering the following scope of work:

- Comprehensive model investigation for testing of general arrangement of diversion structure and hydraulic performance of balancing reservoir cum de-sanding chambers along with their sediment flushing efficiency .
- Flume model investigation for energy dissipation behaviour below the under-sluice and the weir portion of the diversion structure including hydraulic effect of divide wall on fluvial regime.

General View of the Intake Well with Morning Glory Shaft

A comprehensive geometrically similar model was constructed on a scale of 1:16 at the outdoor River Engineering Lab. The model represented about 300m long upstream reach of Chandra river and the left bank nala, Diversion Weir, Under-sluice, side-Intake (on right bank), Intake chamber with Morning

General View of Over Flow Weir

Glory Shaft, Feeder Duct, Balancing Reservoir cum De-sander, HRT Intake, Part of HRT, Silt Flushing Duct, Downstream reach of Chandra River up to the outfall and the Overflow Spillway. General view of the Intake Well with Morning Glory Shaft is shown above.

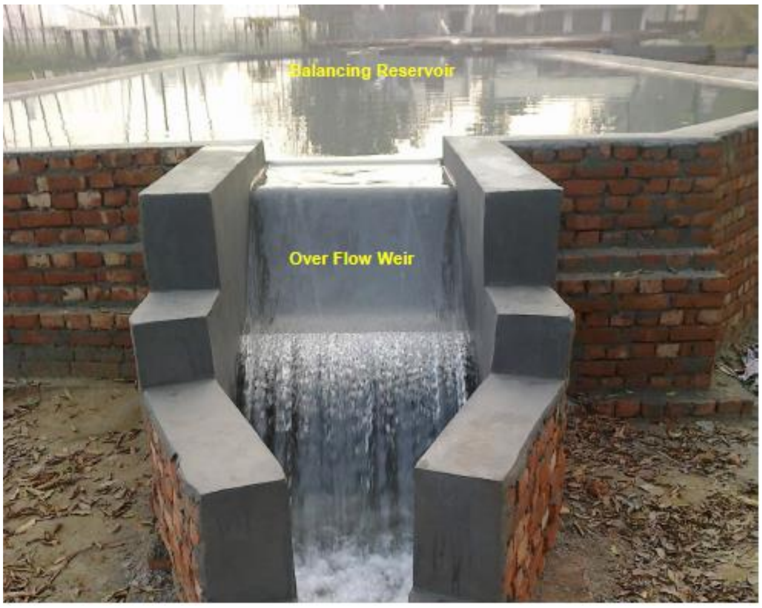
Flow Condition in Flume Model

The findings of the model study is as follows:

1. The ogee shape of the Diversion Weir profile was found suitable to pass the design flood without occurrence of any negative pressure. The coefficient of discharge as observed in the flume model was 2.1.
2. The stilling basin provided at EL. 3444.0m down-stream of the Diversion Weir was capable of pinning the hydraulic jump at the toe of glacis. A maximum scour of 4.2 m was observed at a distance of 30 m from the end of basin in operating condition E2 when the maximum river discharge approached the diversion weir.
3. In the original Under-sluice proposal with flat bed, shooting flow condition was observed downstream of weir axis. No hydraulic jump was formed. The maximum scour of 8 m was observed at 40 m from the end of pucca floor. When a stilling basin similar to that on the downstream of the Weir was provided, a feeble jump was observed in the model at the design discharge in the downstream of Under-sluice partly on stilling basin and partly on mobile bed. A maximum scour of 5.5m at a distance of 40m was noted. A bit excessive scour may be taken care of by providing extra protection measures such as heavy CC blocks of appropriate concrete & size.
4. The configuration of the Intake in conjunction with the Divide wall was found adequate and sufficient as provided in the original design. Extension of the divide wall did not accrue any favourable flow condition in the Under-sluice approach channel pocket.
5. The Morning Glory shaft provided to escape the excess flow that entered through the intake in high flood was not found to be effective under submerged outlet condition as sufficient flow head was not available for driving the waters back to the river.

A View of Deposited Bed Load

6. The size of Intake well (12 m x 15m) without Morning Glory shaft is found adequate to fulfil the desired hydraulic function.
7. The breast wall and the side and roof of elliptical transitions joining Intake well to Feeder duct gate groove was found suitable to guide and regulate the flow conveyance to the Feeder duct.
8. Though the width of Feeder duct was found adequate to pass the design discharge into the Balancing Reservoir cum De-sander, the U-turn layout of feeder duct adds to the excessive head loss, which can be restricted by increase in bed width of Feeder Duct.

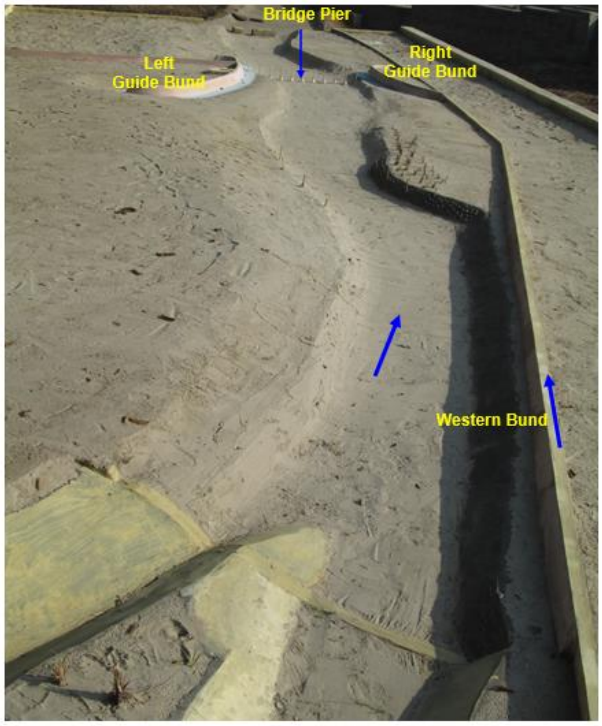


Flow at Over Flow Weir

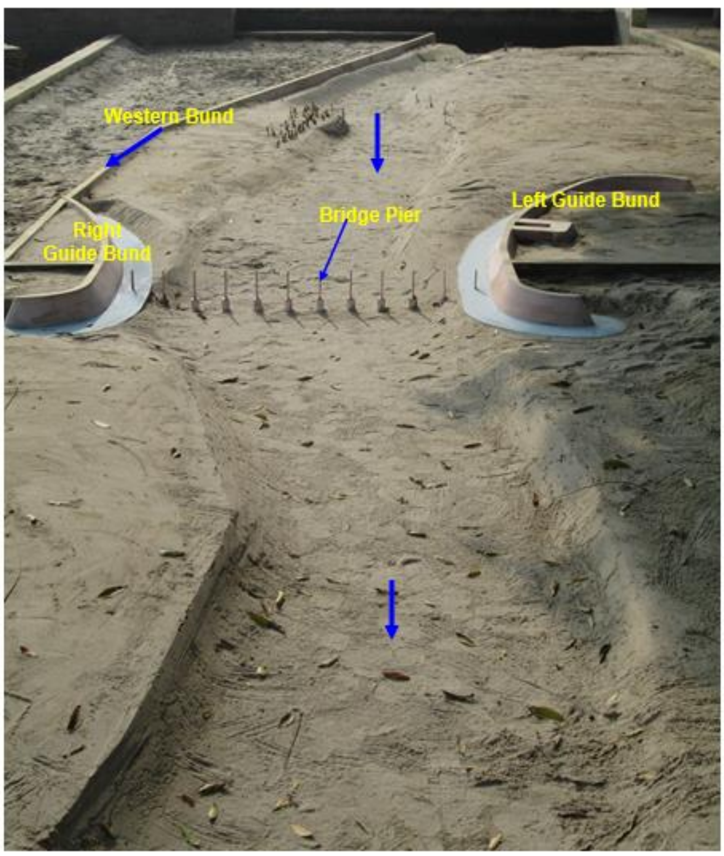
9. Layout of Balancing Reservoir cum De-sander was broadly found to be proper and adequate to fulfil its hydraulic function.
   At FRL the Balancing Reservoir could retain about 90% particles of +0.2 mm and above size and 70% of overall sediment fed in the system.
10. Continuous flushing of sediment through sediment Flushing ducts is not effective. However, with draw-down intermittent flushing operation through one by one chamber at a time, the Balancing Reservoir cum De-sander was cleared off the deposited sediment.
11. The Sediment Flushing duct including the gated opening of 2m x 2m , two number each in a compartment and its out-fall in the Chandra river was found adequate to pass the required flushing discharge.
12. The over-flow weir at the end of Balancing Reservoir cum De-sander in conjunction with normal operation of HRT and sediment Flushing duct could pass the excess discharge out of the 130 cumec entering the Balancing Reservoir cum De-sander at the reservoir level of 3452.3.
13. The radial baffle wall provided around HRT intake did not show any adverse fluvial effect even when Balancing Reservoir cum De-sander was kept at MDDL.
14. The river curvature on the upstream of Diversion Weir is favourable in deflecting the bed load away from the Intake. The effect may be further enhanced by providing deflecting submerged spurs or bed bars appropriately.

Project 16: Physical model study for Telwa Bridge on Bahti River, Sponsored by Bihar Rajya Pul Nirman Nigam Limited, 2013.

A comprehensive physical model of river Bahti was constructed on linear and vertical scales of 160 & 40 respectively. In the model 2.2 km upstream reach 1 km downstream reach of the river in the vicinity of HL RCC Bridge was laid in the sand of appropriate gradation so as to ensure the adequate and proper bed movement as per the layout and Cross-sections supplied by the sponsor. The western bund, bridge guide bunds along with their aprons were represented in brick masonry with surfaces plastered smooth. The bridge piers were moulded in cement mortar and fixed at the proper locations so as to divide the total water way of 329.68 m into 13 equal spans. General view of physical model is shown above.



General View of Model from Upstream



General View of Model from Downstream

The model was run with the designed discharge of 3966 m^3/sec and tail water level was so maintained as to keep the water level at the downstream of bridge at EL 98.606 m. It was observed that the water level at the upstream of bridge piers stabilised at EL 98.90m, indicating an afflux of about 0.3m. The finding also indicated that the design assumption of bridge span and water way as tested on physical model is found correct. The waterway is sufficient and adequate. The model was subsequently run with 1000, 2000, 3000 and 3966 m^3/s and water levels at upstream and downstream of bridge were observed. The findings of the model study is given below

1. The physical model study indicated that the design assumption of 329.68 m bridge water bay is proper and adequate.
2. An afflux of about 0.3 m was observed on physical model at the design discharge.
3. The surface and bed lines of flow are more or less equally distributed within the bride span.
4. The central bays of bridge draw more discharge while all other bays are also reasonably active.

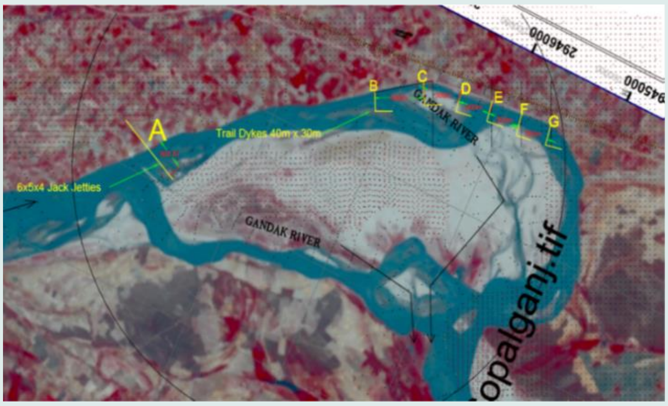
Flow Condition at Left Guide Bund – Design Discharge

5. The left guide bund guides the flow smoothly into the bridge. No bed action was observed at the upstream rounded part of the guide bund.
6. There was no adverse bed action at the junction of right guide bund with the western bund. The length of right guide bund as provided in the design is adequate and guided the flow smoothly into the bridge. However, there was a mild excessive bed action near right abutment.

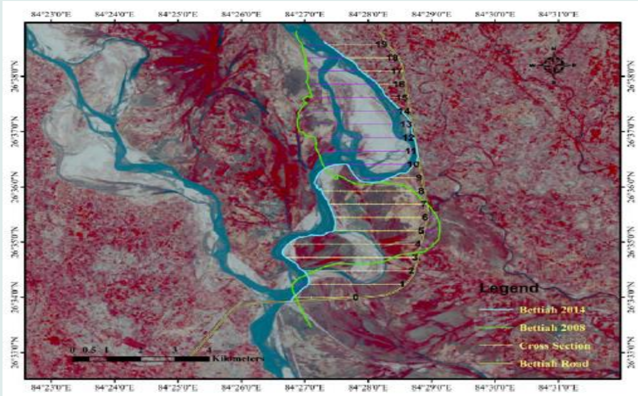
General View of Excessive Bed Action near Right Abutment

7. The length and section of guide bund provided at left and right flanks of river is adequate. The protection work in the slope of guide bund and the apron width of 29 m provided in the design is satisfactory.
8. The depth of foundation of bridge piers and abutments as provided in the design was found sufficient.

Project 17: Comprehensive River Hydraulic Study & Mathematical Modelling for Gandak River Bridge connecting Gopalganj & Bettiah with River Training Works, Sponsored by Bihar Rajya Pul Nirman Nigam Ltd., Patna, 2014.



Satellite Imagery of Landsat 8 acquired on 02-April-2014 with tentative river training measures

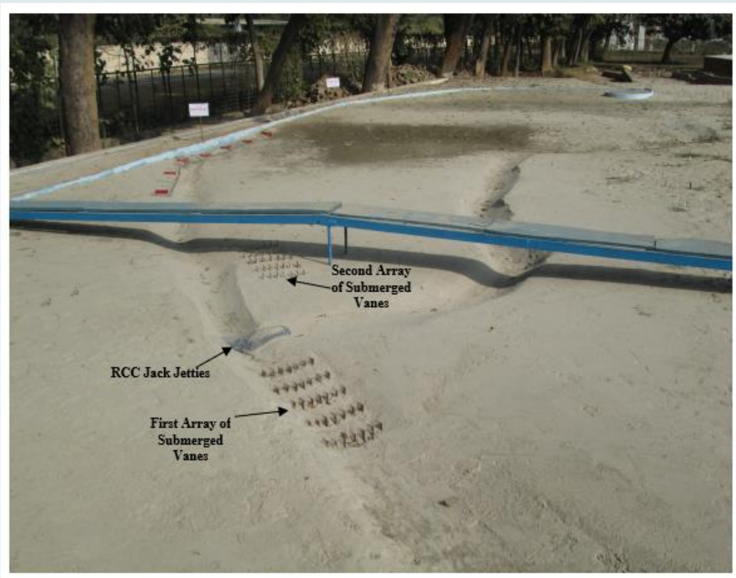


Super-imposed Digitized left bank line map of the river during 2013 and 2014 on the imagery of Landsat 8 acquired on 13-May-2014

The project Sponsor Bihar Rajya Pul Nirman Nigam Ltd referred to Prof. Dr. Nayan Sharma the assignment relating to Comprehensive River Hydraulic Study & Mathematical Modelling for Gandak River Bridge connecting Gopalganj & Bettiah for River Training Works. An aerial visit by the Dr. Nayan Sharma of the study area on 7th August 2013 has brought out that the Gandak River is rapidly migrating towards the Bettiah-Gopalganj road embankment at an alarming rate which appears to be much higher than that of April 2013.

Satellite, Mathematical and Physical model study conducted for the above wok and the findings are as follows

Submerged Vanes and RCC Jack Jetties under running condition



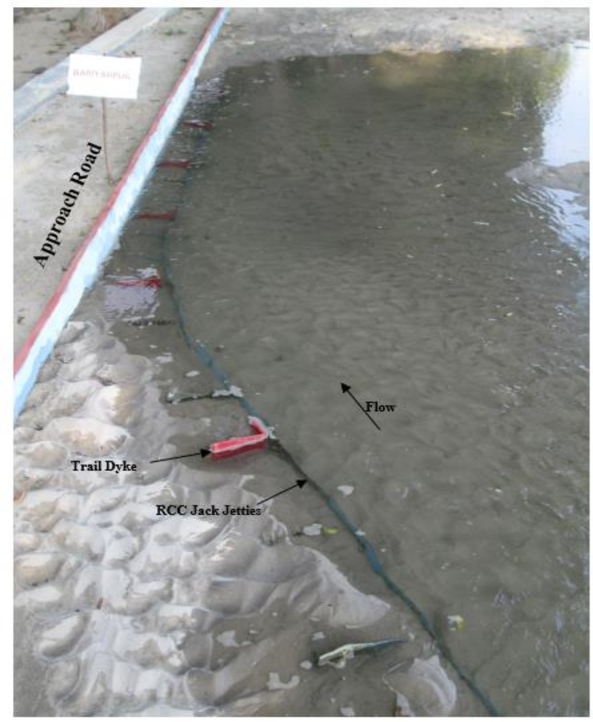
A View of Submerged Vanes and RCC Jack Jetties

1) It can be seen that the Gandak River between C/S 18 and C/S 19 has already changed its course drifting away from the Bettiah road and the river has temporarily abandoned the channel which is hugging the Bettiah road. This may be probably due to the implementation

of channel diversion measures suggested earlier by us as emergency short term works in the Gandak River. The above mentioned channel migration of the main Gandak channel during May 2014 – November 2014 highlights the highly transient nature of Gandak river courses which is a clear pointer to the high degree of its channel instability.

Flow Conditions with Trail Dykes and Jack Jetties D/S of Bridge at high flood discharge

2) The values of velocity and water level obtained on the mathematical modelling are nearly corroborated by the results obtained experimentally on the physical hydraulic model.
3) An array of 5 rows x 8 elements submerged vanes at the channel bifurcation of Gandak river near village Bariyarpur was found extremely effective in activating the right channel and thereby deactivating and silting the attacking right channel.
4) Four rows of 6 x 5 x 4 Jack Jetties in three tiers in the left channel about 300 m downstream of the Submerged Vane array induced more silting in this channel.



Additional View of Trail Dykes in Series

5) An additional similar second array of Submerged Vanes about 800 metres downstream from the first array (at location 'A' near village Mangalpur) further deflected some of the incoming flow volumes towards the right side as desired for protection of Bettiah Road.
6) Six numbers Trail Dykes supplemented with Jack Jetties remarkably reduced the bank erosion and helped in protecting the road near Bariyarpur village by accelerating silting between the dykes
7) Three number Trail Dykes with adequate Jack Jetties have been proposed which were found effective enough to protect the erosion along the right bank downstream guide bund of the bridge near Gopalganj.

Project 18: Physical Model Study for Ganga River Bridge near Sultanganj, Bihar Sponsored by S. P. Singla Construction Pvt. Ltd., 2015.

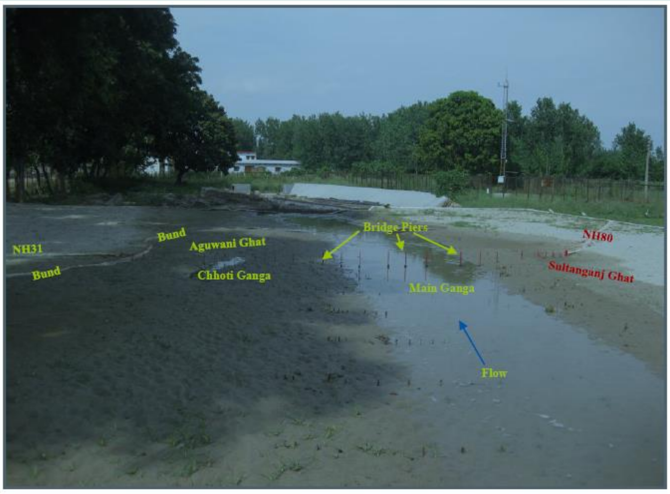
Bihar Rajya Pul Nirman Nigam Ltd. is constructing a four lane bridge across river Ganga between Sultanganj Ghat (Bhagalpur) and Aguwani Ghat (Khagaria) connecting NH80 to NH31. Abutment to abutment gross waterway of the bridge is proposed to be 3160 m divided in 31 bays. The bay width, pier foundation size and the piers vary keeping in view the flow characteristics and usages of the span. The construction and fabrication work is awarded to M/S S. P. Singla Constructions Pvt. Ltd. who, requested Prof. Dr. Nayan Sharma to conduct physical hydraulic model study of river Ganga at the bridge site. The following Scope and Objectives are arrived at after discussions with the sponsoring authority:

a) To investigate the flow behaviour of river Ganga at bridge site
b) To evaluate the distribution of flow discharge in various zones of the bridge
c) Assessment of design scour levels in various zones
d) To evaluate Design discharge for 50 years and 100 years return period

General View of Physical Model

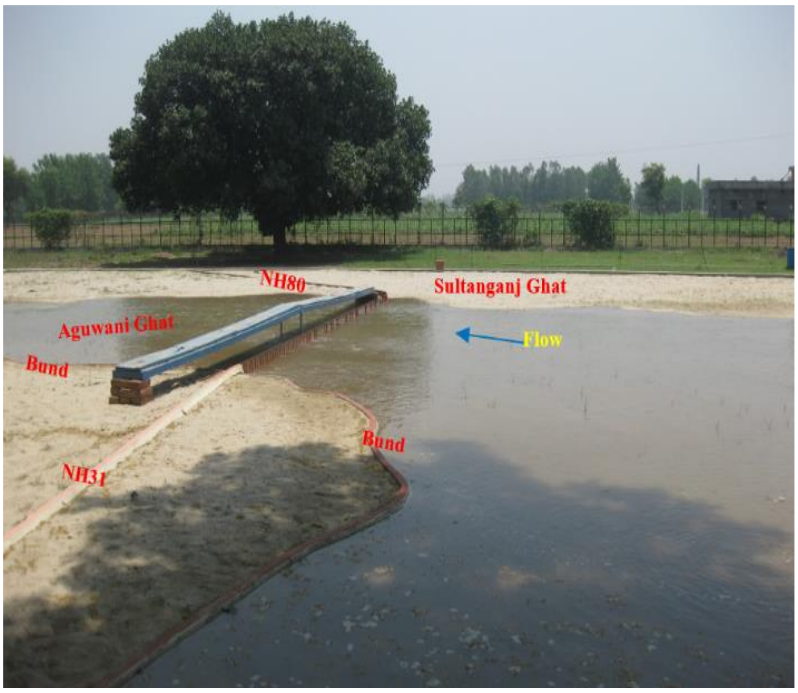
1. The physical hydraulic model runs of the proposed Ganga Bridge at Sultanganj site indicated that the design discharge of 81,284 m^3/s could pass through the prescribed waterway of 3160m at the water level of 36.95m.
2. The physical model study indicated that the Sub Section No. 2 carried a maximum discharge share of about 88% of the design discharge, whereas the Sub Section No. 1 carried a nominal discharge amounting to less than 1% and the remaining about 11% of design flood was conveyed by Sub Section No. 3.
3. The general flow conditions in immediate adjoining upstream zone of bridge at design discharge were observed in the model runs and found to be satisfactory without observing any deleterious parallel or return flow or any visible tendency for island bar formation in the immediate vicinity of the bridge.

4. There was no visible adverse flow pattern along the existing bund on the upstream and downstream of Aguwani Ghat side. However, available free board at HFL is about 1m only considering the top of bund at EL 38m.



Another View of Physical Model

5. Using the hydraulic data observed from the physical hydraulic model studies, the maximum local scour around bridge piers on the basis of CSU equation was found to occur at pier no. 8.
6. The maximum pier scour depth evolved as above on the basis of using physical model hydraulic data in the widely internationally used multi-parameter CSU equation worked out to be 14.04m below general scour level.
7. It is suggested that for the above stated sections, the deepest stream bed elevations around piers may be taken as 12m, 0.8m and 12m respectively corresponding to the design flood of 81,284 m^3/s.
8. Model flow simulation performed within the purview of hydrological, hydrographic and all other related data received from the sponsor, the converging streamlines were critically observed during model runs. The flow pattern indicated that incoming stream flows generally approached the bridge spans fairly smoothly without much significant turbulence.



Side View of Physical Model

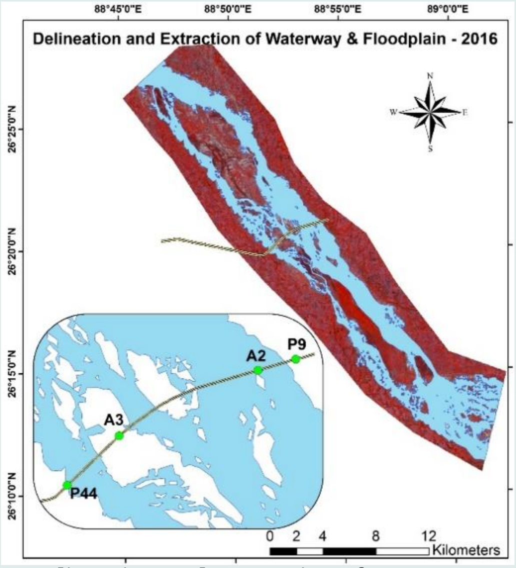
The flow lines coming from the Abutment A2 side were seen to be approaching the bridge centre-line at an oblique angle, not perpendicularly as is desirable. This occurrence of undesirable oblique flows propagating towards the Main Ganga stream may be attributed to the absence of a guide bund along Aguwani Ghat side of the bridge. Notably, significant oblique flows at high floods striking the bridge piers at a skewed angle can potentially cause enhanced horse-shoe vortex formation triggering increase in local scour depth, which may affect bridge stability by encroaching on foundation grip length.

Project 19: Physical and Mathematical Model Study on High Level Bridge over River Teesta with approaches near Haldibari, connecting with Mekhliganj and Haldibari in the district of Coochbehar, West Bengal Sponsored by S. P. Singla Construction Pvt. Ltd., 2016.

The project Sponsor M/S S. P. Singla Construction Pvt. Ltd. referred Prof. Dr. Nayan Sharma the assignment relating to technical study on the proposed road bridge lay-out over the river Teesta with approaches near Haldibari connecting sub-division Head Quarter at Mekhliganj in Coochbehar district of West Bengal state.

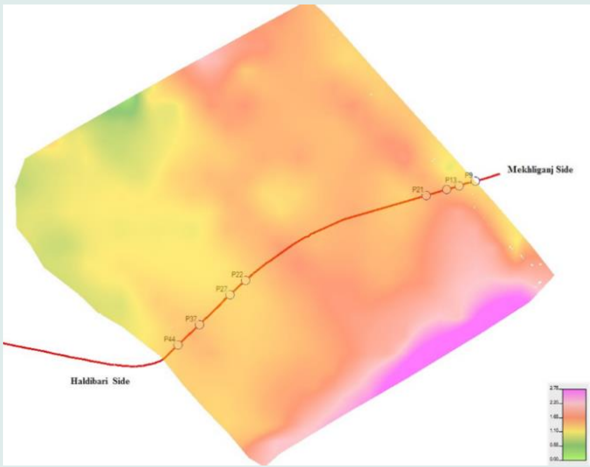
Using the data furnished by the Sponsor, the study has been carried out under the following three different approaches for proper coverage of the related river behaviour for past thirty six years as well as flow simulations with the proposed bridge in position –

1. Satellite image based analysis of river behaviour and channel configuration changes.
2. Mathematical hydraulic modelling with and without the proposed bridge layout.
3. Physical scale modelling of river hydraulic behaviour with the proposed bridge lay-out in position.



Delineation and Extraction of Waterway & Floodplain – Year 2016

Velocity Distribution at 500 Cumec



Velocity Distribution at 21,600 Cumec (With Additional Flow channels)

After careful synthesis of the technical findings of the aforementioned three related scientific studies, the following prime results have emerged as highlighted below.

1. From satellite image analysis, the fluvial landform features on the Teesta River in the bridge site zone are found to be transient in nature and found to be inherently unstable. The sand bar sand bar over which 2.74 km long road embankment is proposed to aligned, is seen to be now dismembered and not existing at all; presently an active river channel is flowing through it. Therefore, creating road embankment on this unstable sand bars will be highly infeasible and not recommended.
2. From the mathematical hydraulic model study, the occurrence of a high afflux of the order of 2.88 m is indicated at the maximum flood discharge of 21,600 m^3/s with the proposed bridge lay-out in position including the road embankment on the sand bar.

Mathematical hydraulic modelling with the proposed bridge lay-out has brought out that at the maximum flood (21,600 m^3/s) the resultant average flood levels (without bridge & embankment) are as stated below-

i) High Flood Level (HFL) from 1-D model - 67.47 m

ii) Flood level without bridge as given by S. P. Singla Construction Pvt. Ltd. – 66.30 m (discharge magnitude not indicated)

iii) Affluxed water level from 1-D model - 70.35 m after bridge and embankment construction

General View of the Model from Downstream

The mathematical modelling also indicated increment of velocity to about 3.18 m/s at above stated maximum flood, which is found to be more than twice the velocity under no bridge condition.

Flow Condition at 20,784 m3/s from Upstream

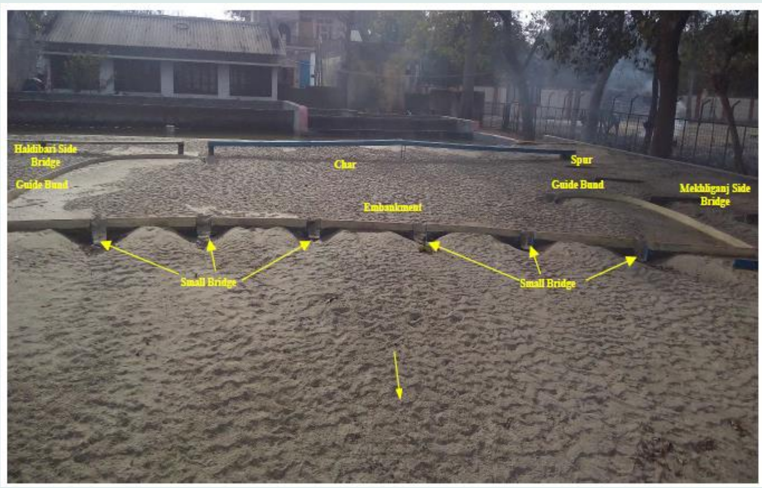
3. The physical scale hydraulic modelling study has also corroborated almost similar values of affluxed flood levels as have been yielded by the mathematical hydraulic modelling. Physical hydraulic model runs have provided the information on discharge distribution at maximum flood flow (21,600 m^3/s) as 18.5%, 29% and 52.5% for the Mekhliganj channel, six small road embankment bridges (50m each) and the Haldibari channel respectively. It could be discerned from physical model runs that the six small bridges have very actively discharged the flood flow at maximum flood.
4. It is strongly apprehended that such hyperactive flood flow conveyance behaviour by these six small bridge waterways through the middle of the river may potentially attract sizeable stream-flow volume in course of an y big future flood flow event putting the proposed road embankment on the Sand bars at a very grave risk.
5. The elliptical guide bunds are not found conducive for such an intricate bridge lay-out configuration and are rather considered to be detrimental with respect to achieving desired fluvial behaviour especially along the central position of the bridge lay-out.

6. In the physical model runs, the two asymmetrically laid out guide bunds have created two large dead water pools (near their curved heads). These two pools are likely to induce heavy silt deposition which in its wake is apprehended to give rise to undesirable flow disturbances due to asymmetrical channel constriction. Eventually, such a fluvial development will not only adversely affect the hydraulics of six small bridge waterways, but also further adversely raise the flood levels along the road embankment thereby jeopardizing its safety by overtopping it.

General River Bed Condition after Model Run

RECOMMENDATIONS:

1. After carefully analysing the results of the three related approaches of the study, the proposed configuration of the bridge lay-out is not considered to be safe and stable, and emphatically not recommended for adoption.



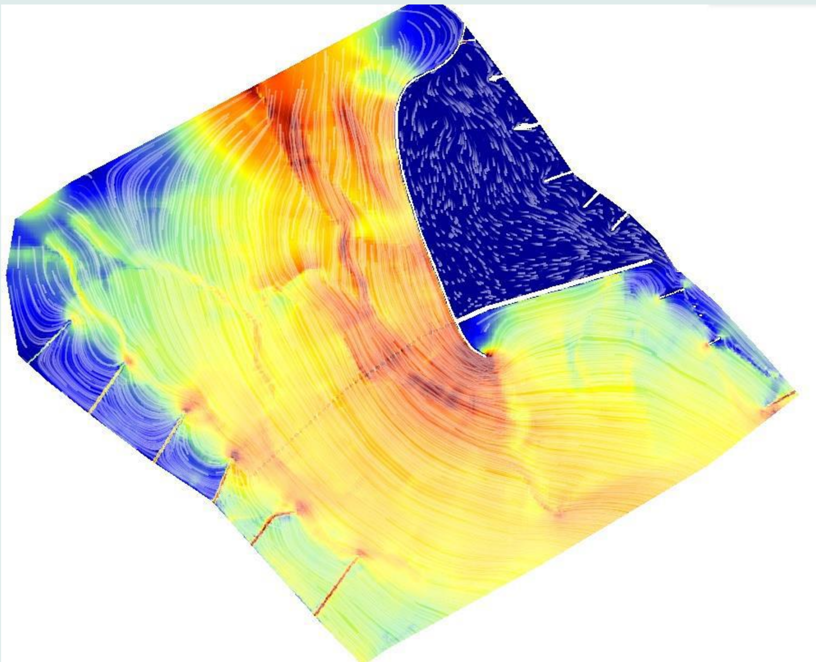
River Bed Condition in the Downstream of Char

2. Considering the highly braided character of the Teesta river course and inherent instability of sand bars, increase in velocity and very high afflux due to obstruction caused by long embankment, the recommended best option will be to bridge the entire waterway with provision of cost effective river training works at both ends of the river. The other option may be partially bridging the waterway with very limited channel constriction supported by very robust river training works (which may entail recurring sizable maintenance and repair depending upon passage of annual flood events magnitude). The performance and behaviour of the revised adopted design lay-out in latter option will have to be subjected to mathematical and physical model studies with the revised bridge lay-out for determining appropriate design parameters (scour depth, velocity, flow depth etc.) along with thalweg channel migration behaviour, dominant flow lines direction, & flow obliquity etc.
3. H.F.L. for design purpose should be revised to 68.15 m corresponding to Design discharge of 21,600 m^3/s as obtained from Physical scale model runs.
4. Maximum (deepest) scour level may be considered as 56.52 m as obtained from the mathematical model runs.

Project 20: Physical and Mathematical Model Study for Proposed Bridge over river Teesta at Haldibari in Cooch Behar, District- West Bengal, Sponsored by NBCC-I, PWD, West Bengal, 2017.

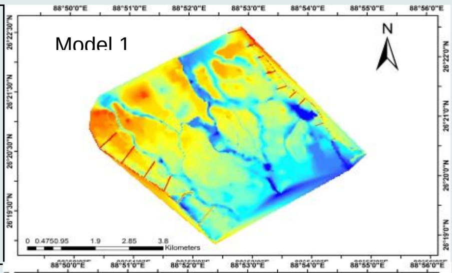
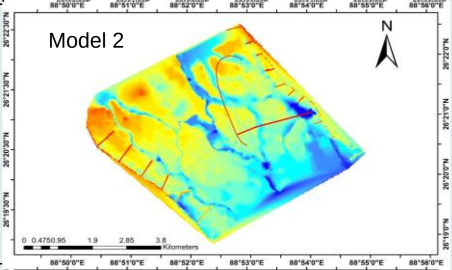
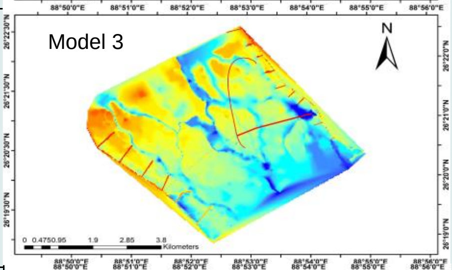
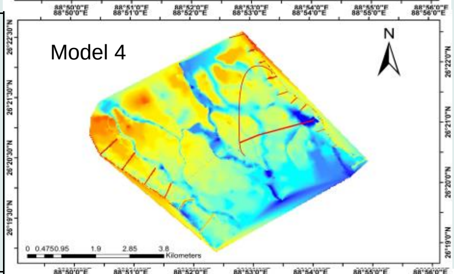
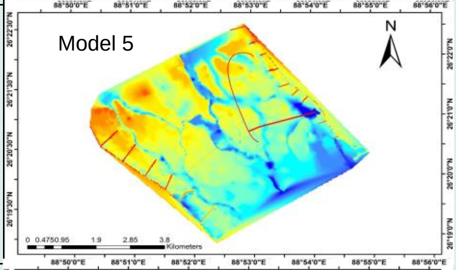
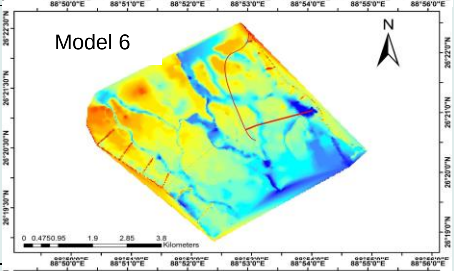
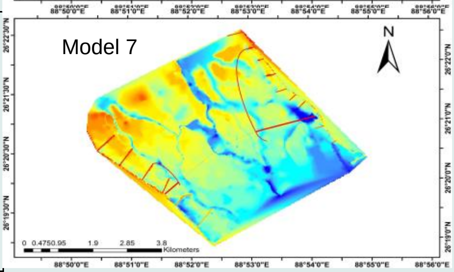
A Mathematical and Physical model Study on High Level Bridge over River Teesta connecting with Mekhliganj and Haldibari was previously conducted in IIT Roorkee. On findings of the above study sponsor PWD, West Bengal again contacted to IIT Roorkee with the new bridge alignment. The proposed bridge consists of 41 spans. The width of all the spans is kept equal 60 m centre to centre of the pier. An elliptical guide bund of 2460 m length perpendicular to the bridge axis at the point is proposed to be constructed on Mekhliganj side. An embankment will thereafter be constructed to cover the existing Mekhliganj side channel and join to the via duct spans at Mekhliganj side before connecting the road. For the above new bridge alignment Mathematical and Physical Model study conducted in IIT Roorkee. The objective of the mathematical model setup is to develop a two-dimensional HEC-RAS model, and find ways to find most suitable hydraulically stable layout. A two-dimensional HEC-RAS model is developed with seven different layouts including present condition. The layouts of model setups is given below

The findings of the mathematical model is given below:



Flowlines for Model 6

1. Rectified floodplain DEM was constructed by integrating SRTM, bathymetry and channel data. Using the rectified DEM, HEC-RAS model was able to reproduce inundation dynamics in terms of inundation extent, water-surface elevation and velocity vectors.
2. Mathematical model tests were conducted to determine the different hydraulic characteristics for proposed Teesta Bridge. Seven different Guide bund layouts were considered during the testing, consisting of the original (unmodif ied) river condition.
3. Models M2, M3 and M5 were not preferred due to formation of excessive high velocity zone near Mekhliganj side via duct. For M2 condition, average velocity was observed as 5.84 m/s near via duct of Mekhliganj side.
4. Average afflux in upstream of bridge site for model 7 was relatively higher than Model 6.
5. Highest average flood level against all the model (M1 to M7) was observed at 68.43m.
6. Flowlines of Model 7 suggests that there is chance of overflow due to uneven levels of spur and guide bund. In that case levelling of spur is required as per level of guide bund.
7. Lay-out of Model 6 is recommended as it performed best (hydraulically stable) among all tested models (M2 to M7). 42
8. Highest flood level for model 6 is estimated at 68.31 m, so design flood level for embankment and guide bund would be 68.40 m. It is also in coherence with physical model.
9. Layout details of Embankment and Guide bund for field use is attached as annexure.

Model 1 (M1)	Without Bridge and Embankment in position	
Model 2 (M2)	Bridge Span (Same as suggested by Lea Associates) with Bridge and Embankment in position + left Guide bund layout at 90 degree with approach road (Haldibari to Mekhliganj)	
Model 3 (M3)	Bridge Span (Same as suggested by Lea Associates) with Bridge and Embankment in position + left Guide bund layout at 100 degree with approach road (Haldibari to Mekhliganj)	
Model 4 (M4)	Bridge Span (Same as suggested by Lea Associates) with Bridge and Embankment in position + left Guide bund layout at 110 degree with approach road (Haldibari to Mekhliganj)	
Model 5 (M5)	Bridge Span (10% More Than originally suggested) with Bridge and Embankment in position + left Guide bund layout at 90 degree with approach road (Haldibari to Mekhliganj) + 240 m Shifted towards Mekhliganj side + Upstream portion of guide bund kept open	
Model 6 (M6)	Bridge Span (10% More Than suggested) with Bridge and Embankment in position + left Guide bund layout at 90 degree with approach road (Haldibari to Mekhliganj) + 240 m Shifted towards Mekhliganj side + Upstream portion of guide bund kept closed using upstream nose modification	
Model 7 (M7)	Bridge Span (Same as suggested by Lea Associates) with Bridge and Embankment in position + left Guide bund layout at 90 degree with approach road (Haldibari to Mekhliganj) with 500 m Shifted towards Mekhliganj side +Additional right guide bund with embankment (suggested by Lea Associates)	

Physical hydraulic model of river Teesta was constructed at outdoor river Engineering Lab keeping linear scale of 1:300 and vertical scale of 1:50. The vertical exaggeration 1:6 is within acceptable limit which is in accordance with existing practice of most hydraulic research stations. The vertical exaggeration induces desired mobile river bed movement simulating the prototype condition The discharge scale on Froude similarity criterion works out to 1:1,06,066. River cross-sections were laid as supplied by the sponsor. The river bed was dressed with the locally available sand of average diameter 0.12mm. The river reaches of 3km on the upstream of proposed bridge and 2 km downstream were represented in the physical model. All the existing spurs in the study zone on Haldibari side as well as Mekhliganj side both on upstream and downstream were represented rigid moulded in cement mortar. Marginal bunds on both side included in the represented area of the physical Hydraulic model was also laid rigid, constructed in cement mortar. Water level observation gauges were installed in the model on both the bank of river Teesta at 6 locations. The abutment on Haldibari side was marked zero while other locations were kept at 1500 m upstream and 1500 downstream of the abutment.

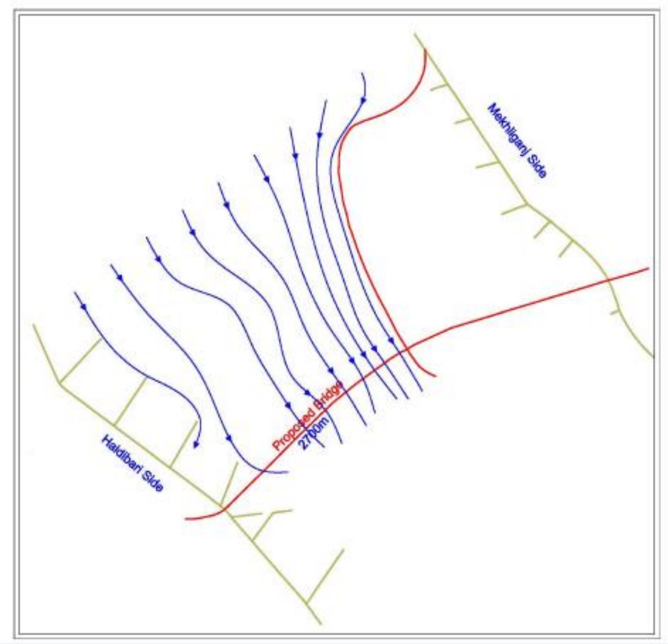
The findings of the physical model is given below

General View of the Model without Bridge from Upstream at 21,600 cumec discharge

General View of the Model Final Proposal M6 at 21600 m3/s

1. The physical model indicated that the average water level on the bridge site at design discharge of 21,600 m^3/s with final proposal of the bridge and the guide bund (M6) was found at El. 68.5 m.

2. The flow pattern depicted by surface flow lines observed on physical model inferred that the final layout of bridge and guide bund (M6) is satisfact ory.
3. It was observed on physical model that the guide bund was appropriately directing the flow into the bridge without any deleterious separation zone.
4. The final design parameters of the scour protection apron for the guide bund should be finalized after due consideration of the soil properties of the bridge site and recommendations of IRC and BIS.



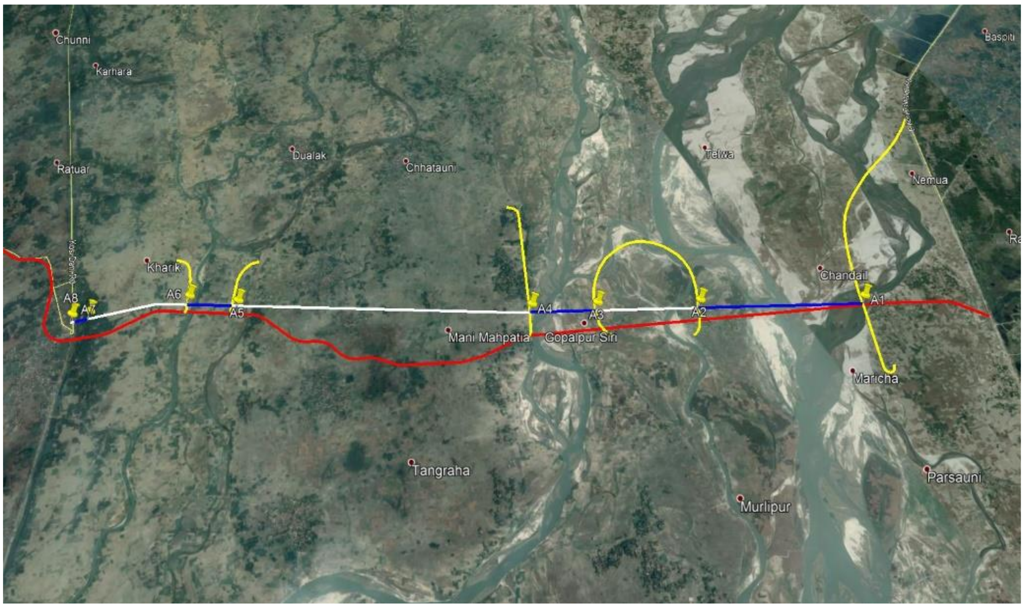
Surface Flow Lines at Design Discharge with Proposal M6

5. The observed velocities in various bridge spans on physical model, which indicate some improvement in discharging behaviour of the end spans along Haldibari side without the nearest upstream spur condition. This improvement is expected to be further higher in the prototype flow condition.
6. The maximum velocity in the physical model with the final proposal of brid ge spans and guide bund (M6) was observed about 2.82 m/s without removing the nearest spur upstream of the bridge on Haldibari side.
7. On the basis of physical model study conducted with the data supplied by the sponsor, it was found that simulated behaviour of final proposal with 45 spans of the bridge having guide bund aligned at 900 to the approach road embankment and extended by tying with the flood embankment (M6 vide Mathematical model study) was found superior to the earlier one and thus recommended for adoption at site. The via-duct spans as provided in the earlier layout may be retained.

Scour on Spur Nose Initial Proposal M2

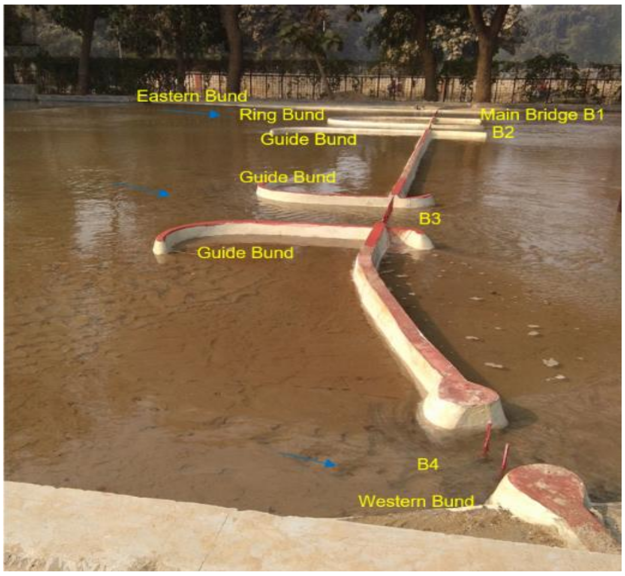
Project 21: Physical modelling studies for Kosi river covering the proposed bridge over near Supaul under Bharat Mala Project of NHAI in Bihar, Sponsored by VKS Infratech Management Pvt. Ltd., 2017

A high-level bridge is proposed on river Kosi connecting Supaul / Saharsa on the left and Bheja on the right bank of the river. VKS Infratech Management Pvt. Ltd. on behalf of Project Director PIU-Darbhanga, NHAI requ ested Dept. of IIT Roorkee to conduct Physical Hydraulic Model study for recommendation on the adequacy and efficacy of the bridge layout and its appurtenances. River Kosi flows get divided in many channels including the main channel, channel no. 2, channel no. 3 and channel no. 4 besides a narrow channel between channel no. 3 & 4. There is on e more channel near western Kosi Bund (Channel no. 5). However, the channel no. 2 is very near the main channel. The main bridge on main channel (B1) consists of total water way of 2020 m comprising 39 spans of 50 m each and 35 m wide two end spans on either side of the bridge. A guide bund is proposed on left side to direct the flow into the main bridge. It is to be connected with the eastern Kosi bund which will also protect the inhabited nearby area.



Showing two Proposed Alignments of the road. Final Proposed Bridges are shown on Final Alignment No. 2

A physical hydraulic model of river Kosi including the bridge area was constructed at the outdoor River Engineering Lab. A reach of about 4 km upstream and 3 km downstream from the proposed bridge axis was represented in the model. Brief



General View of the Model from Right Bank – Recommended Final Proposal

recommendation of Physical model study is presented below:

1. Two layouts of final proposed alignment were tested on physical model. One layout Alignment -1 follows the existing road while the oth er layout Alignment – 2 is kept straight. Initially the first layout has been model tested and reported in the Interim report. The second one was also tested and was found that the straight alignment is superior considering hydraulic performance and being very less susceptible to formation of eddy pockets. On the basis of hydraulic performance, the straight alignment is therefore recommended to be adopted at site.

General View of the Model from Upstream – Recommended Final Proposal

2. Lengths of the bridges were finalized as follows:

a) 2020 m long bridge on left main channel on Supaul / Saharsa side.

b) 800 m long bridge on channel 3. Its layout was kept 175 m from centre line towards right and 625 m towards left.

c) A combined bridge for narrow subsidiary channel and Bhuthi Balan river having a length of 550 m was finalized after finding its better hydraulic performance.

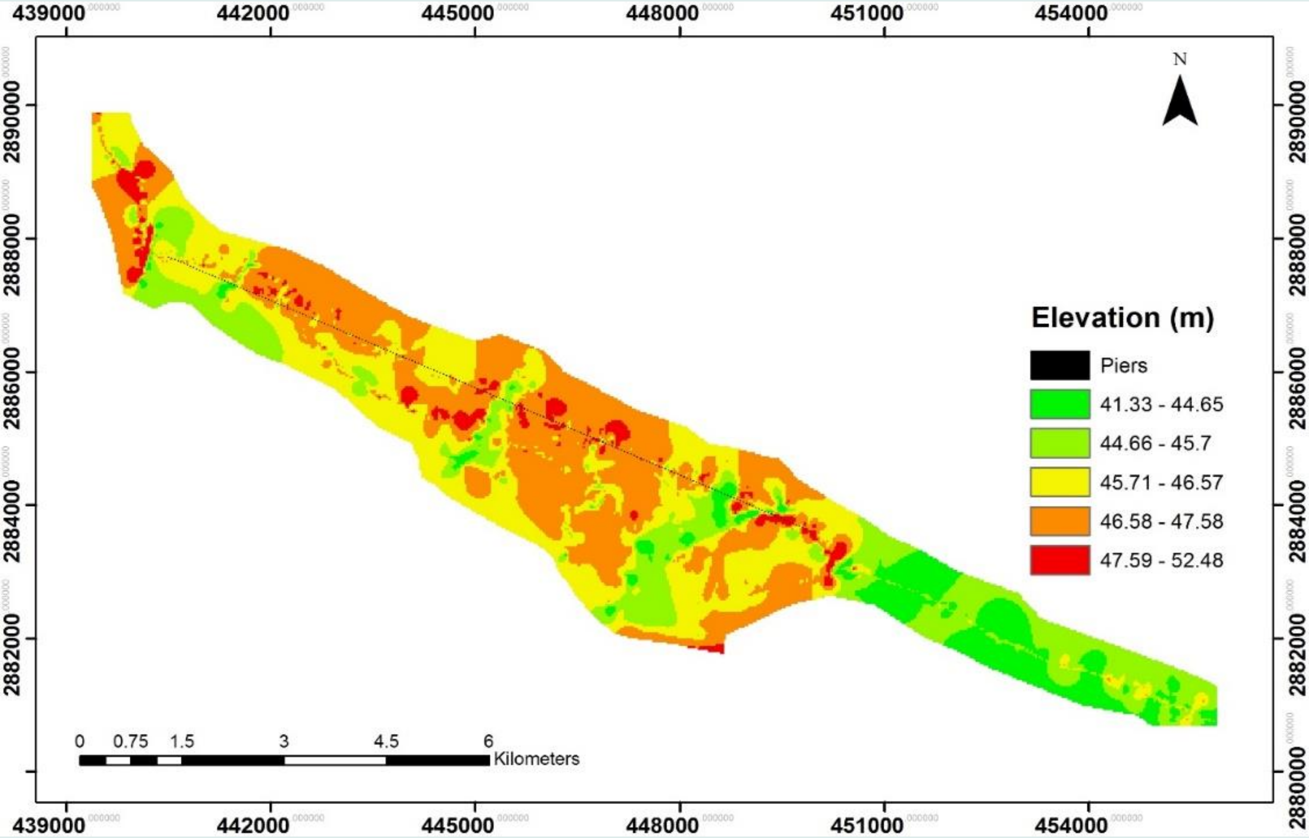
River Bed Condition in the Bridge on Bhuthi Balan River at Design Discharge with Guide and Ring Bunds

d) 150 m long bridge across channel 5 near western Kosi Bandh.

3. An elliptical guide bund, 3400 m long, on the left bank of the main bridge B1 extended to join the eastern bund was recommended and found directing the river flow effectively into the bridge without any flow separation or stagnation. (Please see the final report on “Physical Hydraulic Model Study of Kosi River Bridge joining Bheja to Supaul / Saharsa” for more detailed recommendations).

Project 22: Mathematical Model study of Bridge on river Kosi at Bheja to Supaul, Sponsored by NHAI, New Delhi., 2018.

To minimize the recurring maintenance cost of guide bunds, embankment protection works, cost of LA and hence the overall cost, the client advised to study a longer bridge option with minimum river training/protection works. Accordingly, IIT Roorkee was advised to carry out the mathematical model study to determine optimal bridge length to minimize the river protection works, maximum scour depth and protection works. The bank to bank width of the river was measured as 11.2 km and a bridge length of 10.2 km with 400m of approach road on western bund side and 550m on easte rn bund side was considered for mathematical modelling.

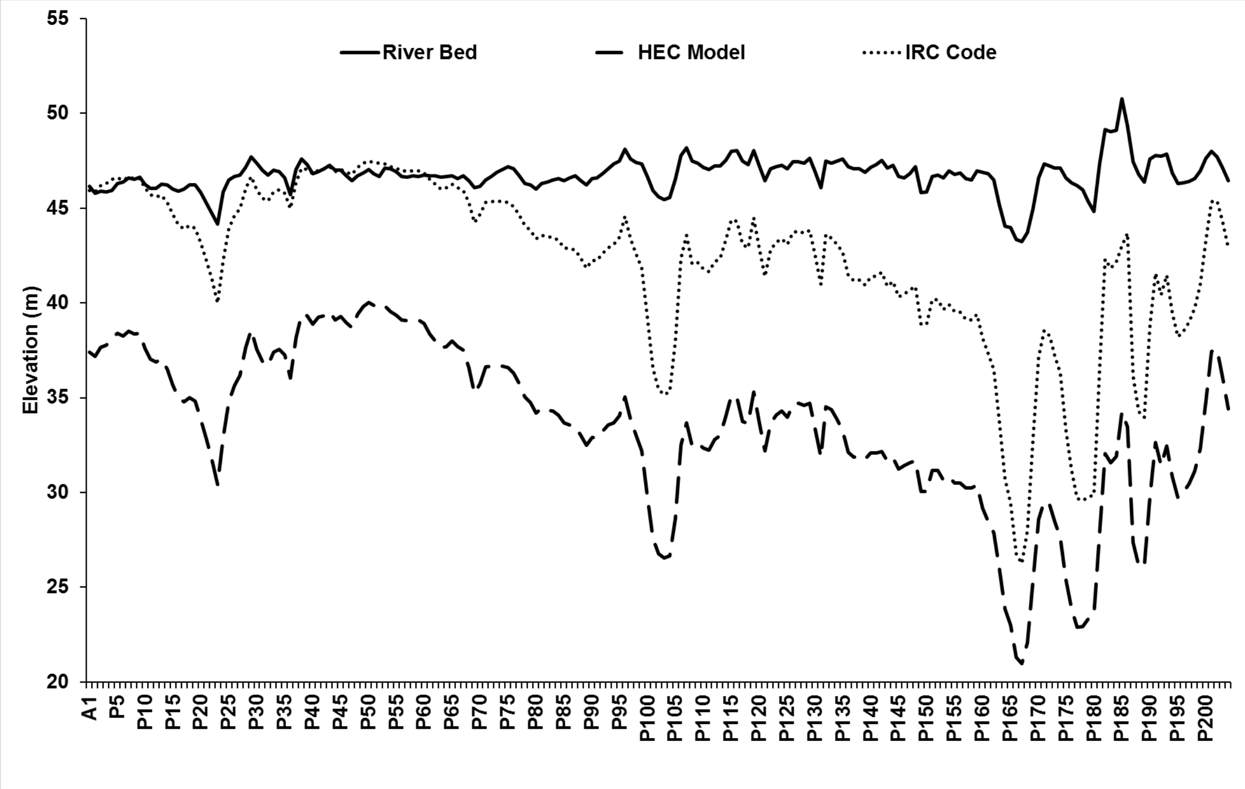


Bathymetric Model of the Study Area

The findings of the Mathematical modelling as given below

1) A bridge length of 10.2 km with 400m of approach road on western bund side and 550m on eastern bund side, was found to be suitable and hence recommended with adequate protection of slope and launching apron. This layout will not necessitate the provision of guide bund. Further reduction in bridge length may compel to construct guide bunds.

2) The estimated maximum scour depth from HFL using the integrated HEC-GIS was found to be 29.03 m, whereas the maximum scour depth from HFL using the HECIRC Code Method was found to be 23.75 m.



Scour Results at Bridge Site (Kosi)

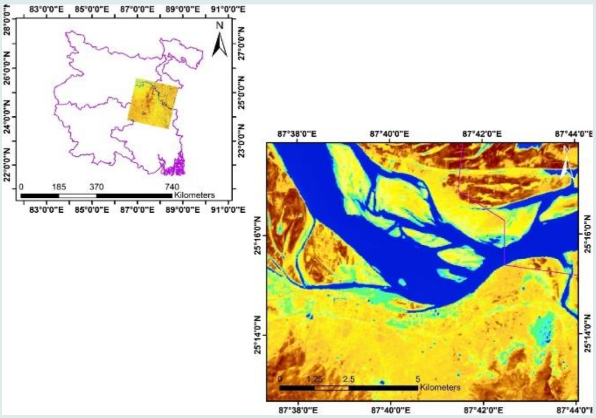
3) Furthermore, the estimated maximum scour depth from HFL using the Direct IRC Code Method was found to be 28.62 m.

4) The maximum scour depth of 30.0m was recommended, considering the maximum scour depth obtained from different methods adopted in mathematical model and IRC-5:1998.

5) Adequate Protection work of approach road embankments are required. The thickness required for slope protection was found to be in the range of 300mm – 600mm, whereas the length of launching apron ranges from 5m – 30m for U/S and 2.5 m – 15m for D/S of the approach road embankment. The thickness of 600mm to 900mm for launching apron was found suitable for sustaining the hydraulic condition of Kosi River.

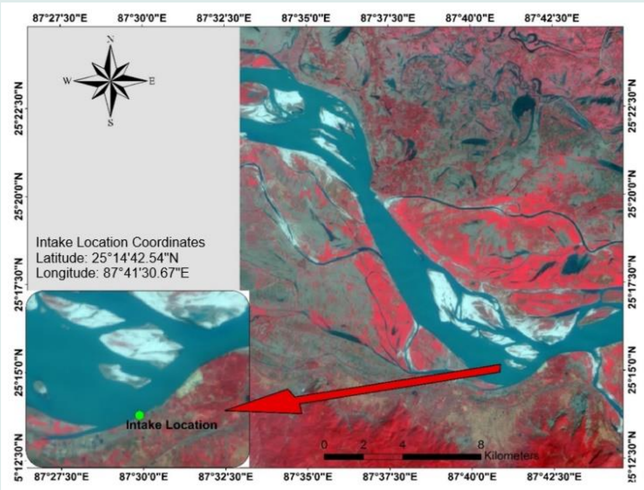
Project 22: Model Study for Water Intake Structure on Ganga River at Sahibganj for 2x800 MW Godda Thermal Power Project, Village: Motia, District: Godda, Jharkhand, India, Sponsored by ADANI POWER (JHARKHAND) LTD., 2018.

Adani Power (Jharkhand) Limited, is a subsidiary company of Adani Power Limited, which has been formed to develop 2 x 800MW Thermal Power Plant in Jharkhand. They have identified Thermal Power Plant (TPP) location near village Motia in Godda district of Jharkhand. The water linkage of the project is envisaged from River Ganga, about 36 MCM annually will be supplied to the TPP. Consultancy services is required for finalizing the location of water drawl point with other details like conceptual intake arrangement etc.



Study Area at Sahibganj

Against the above background, Adani Power (Jharkhand) Limited has contacted Prof. Dr. Nayan Sharma for providing consultancy services. The key objective of the consultancy assignment is to give a detailed hydraulic design of a River water intake structure to withdraw 36 Million Cubic Meter (MCM) water during June – December months from Ganga River from a suitable location in Jharkhand, convey the water to desilting chamber for treatment and sediment removal, and to convey the water through a pipeline to the Godda TPP.



Satellite Image of Ganga River at Sahibganj in year 2017 (December)

Following findings are derived from the present scientific study:

1. The River gauge data are independent with statistical stationarity at 5% significance level. Outlier assessment shows no presence of outliers (either high or low) in the dataset for both the stations at Azmabad on Ganga and Baltara on Kosi.
2. Considering Generalized Extreme Value Distribution, flood frequency analysis using the recorded data for 100 Years return flood is estimated as 88434 m3/s at Sahibganj Site and corresponding RL of the water level is at 28.47m.

Water Intake Structure 20 m away from the Bank

3. Well type intake is desirable due to large fluctuations in water level. As water can be drawn from the river in June to December months the silt content will be very high during this period excepting the receding flow regime of hydrograph. In such situations, sinking well type intake with desilting arrangements is suitable. Sinking well system should be adopted for avoiding any erosion and siltation in and around the navigation channel.

Side View of Model

4. From the satellite imagery based analysis, the river bank reach between the ship repair terminal and RO-RO is seen to be suitable for intake location considering the minimum bank changes. Intake location has been identified at Lat: 25°14'42.54"N; Long: 87°41'30.67"E. The area upstream of ship repair yard is not suitable for intake due to frequent changes in the river bank.
5. From the satellite imagery based study, the location of Intake comes under the water pocket for June to December months.
6. From the satellite imagery study of Char area, it was observed that the Char area is moving away from the probable intake site and the area of char is also shrinking. Evidently this emerging channel development is likely to attract more volume of stream flows in near future which may be conducive towards fairway maintenance as well as reduced siltation due to enhanced sediment transport capacity.

Upstream View of Model in Running

7. It could be seen from the multi-date satellite imagery based analysis that the proposed IWAI installations as well as proposed water intake structure location may not appear to be impacted by processes of any possible induced siltation.
8. Based on satellite imagery analysis it can be stated that the proposed water intake structure do not appear to have any impact on navigational path of the river as the thalweg line is at significant distance from the bank.
9. The physical model studies indicate that the proposed location of water Intake structure is situated on the relatively stable outer bank along concave bend in the right side of river Ganga which exhibited no adverse flow pattern.
10. Similar trend could be ascertained from the mathematical model studies wherein minor changes in fluvial parameters (of the order of 1%) is seen to occur near Intake Location after placement of Intake well in the river and there seems to have minimum chance of sedimentation during high flow.
11. The results suggest that there is minimum chance of sedimentation during average flow of July to November. The possibility of sedimentation (using critical shear approach) exist in the river system during December to June.
12. The magnitude of the scour observed in the model close to the bank is of the order of 3 m.
13. Pattern of probable sediment transport will not change significantly after placement of Intake well at proposed location.