Regulation of the flood in October 2009 at the Srisailam project in India
• Name of Dam: NSRS Srisailam Project
• Year of Completion: 1984
• River / Basin: Krishna in Peninsular India
• Nearest city: Hyderabad
• Type: Gravity/Concrete
• Height above lowest foundation: 475 feet (145 m)
• Length of Dam: 1680 feet (512 m)
• Top level of dam: +904 feet (275.539 m)
• MWL: +892.00 feet (271.881 m)
• FRL: +885.00 feet (269.748 m)
• MDDL for irrigation: 854 feet (260.299 m)
• Sill level of the RC gates: 830 feet (252.984 m)
• MDDL for Power: 798 feet (243.230 m)
• Volume content of Dam: 19,53,000 cum
• Reservoir area: 616.42 sqkm
• Purpose: multi-purpose hydel
• spillway capacity: 11,10,300 cusec (31,440 cumec) at FRL and 13.20 lakh cusec (37,378 cumec) at MWL
• Dam design: for a thousand year return flood of 20.20 lakh cusec (57,200 cumec)
• installed capacity : 1670 MW
• two powerhouses:
  left bank powerhouse : 900 MW (6 X 150MW)
  right bank powerhouse : 770 MW (7 X 110 MW)
• reservoir capacity at FRL : 263.63 TMC(7465 MCM)
• spillway vents : 12 nos. of 60 feet x 55 feet(18.288m x 16.764m) with radial crest gates
• restriction imposed that the end gates of no.1 and no.12 be operated during extreme floods only.
• magnitude of the present flood : 25.50 lakh cusec (72,207 cumec)
• unprecedented rainfall received during September 29th to 2nd October, 2009.
• rainfall ranged from 344mm to 560 mm.
• bulk of rainfall occurred below the major storage reservoirs of upper riparian States without giving any scope for flood moderation.
• unprecedented floods occurred between 2.10.2009 to 6.10.2009 and inflow of 25.50 lakh cusec (72,207 cumec) on 2.10.2009 occurred.
• earlier recorded highest flow of 10.60 lakh cusec (30,015 cumec) occurred on 7.10.1903.
• design flood of the dam is 19.55 lakh cusec (55,359 cumec).
• max water level recorded: + 896.50 feet (273.253 m)
• max discharge through spillway: 14,80,400 cusec (41,920 cumec)
• duration of high flood: nearly 78 hours
• end gates in vents 1 and 12 were also opened
• successful routing of more than 600 TMC (16,990 MCM) of flood over 600 kilometers of river length.
• earlier, high floods had occurred during 1998 and right side powerhouse inundated under the tail water of the dam due to opening of 12th gate.
• sudden surge in inflows was a result of record rainfall in the un-intercepted catchment area downstream of Tungabhadra dam and Jurala project but upstream of Srisailam dam.
• as the run off was in the area not covered by the gauging stations, the magnitude of the inflows received could not be anticipated well in advance.

• as a result, pre depletion of the reservoir was not possible to such an extent that the upstream water levels could be limited to +892.00 feet (271.881m).

• however, the reservoir level was brought down from +884.90 feet (269.717 m) at 19.00 hrs on 30.09.09 to a level of +880.60 feet (268.406 m) by 23.00 hrs on 01.10.2009, depleting to an extent of 27.289 TMC (771.738 MCM)
Filling up of the reservoir

• after the floods of 1998, the Committee set up by the Government went into the issue of the date by which the Srisailam reservoir could be filled up to FRL.

• it noted that, the reservoir being utilized for power generation, it would be advantageous to build up higher levels as soon as possible and that it could be used for moderation only when extreme floods warrant it.

• Srisailam reservoir is being used for conservation while the Nagarjunasagar (NSP) reservoir (about 100km downstream of Srisailam dam) for moderation of the flood.
from the past experience it could be seen that if the reservoir is not filled up to the FRL even by September 15th, the success rate of the utilizations for power generation and irrigation needs would be coming down.

after the floods in 1998, exercises were carried out to determine the extent of pre depletion required to limit the reservoir level to the MWL, in case of occurrence of the design flood of 19,55,000 cusec (55,359 cumec).

exercises indicated that even with advance forecasts, the MWL cannot be limited to + 892.00 feet (271.881 m) because of the spillway constraints (operation of end gates) and the period of advance notice that would be available being less than 24 hours.

this has now been proved correct.
• exercises carried out earlier had pin pointed the need to put in place an effective advance flood warning mechanism.

• though the flood intensity downstream of the two upstream projects- Jurala and Sunkesula could be known in advance, there is no arrangement to monitor and obtain the inflow data from the intermediate catchment. It is, therefore necessary that gauges are set up in this area to obtain real time data.
Flood monitoring

• water level in reservoir on 30.9.2009 at 6 AM was +884.40 feet (269.565 m)
• however keeping in view the flows observed at Jurala Dam and in Tungabhadra river (Kurnool) and ongoing rainfall, spillway gates were operated from 7 PM on 30.9.2009 with a discharge of 1,15,114 cusec (3259 cumec) and further gradually increased to 5,34,650 cusec (15,139 cumec)by 6 AM on 1.10.2009
• keeping in view of the increasing trend of flood on 1.10.2009 morning, 10 gates were further raised to their total height with a discharge of 8,99,046 cusec (25,458 cumec) including power draft.
• further the 11th gate (Gate No 12) was operated at 9 PM on 1.10.09 and discharge of 9, 66,052 cusec (27,355 cumec) including power draft allowed.
• reservoir was depleted to +880.6 feet (268.406 m) by 11 PM on 1.10.2009 from +884.90 feet (269.717 m) at 7 PM on 30.9.2009
• at MWL, the discharge from dam is 13.2 lakh cusec which is far below the peak inflow and it is the reason for built up of reservoir upto +896.50 feet, though all the gates were opened.
• by 9 PM on 1.10.2009, discharge of 4,50,000 cusec was observed at Kurnool gauge (Tungabhadra) and 11 out of 12 gates were already opened at Srisailam.
• unprecedented high inflows started increasing the reservoir level and touched the FRL at 5 PM on 2.10.2009.
• inflows in reservoir on 2nd October evening onwards were about 25.50 lakh cusec, which had resulted in impounding of flood water up to +896.50 feet on 3.10.2009 at 12.00 noon.
• at 11 30 am on October 3, vibrations were observed at the level of the road deck and hoist bridge when the upstream water levels were in the order of +896.00 feet and above.

• Gate No 1 and other gates were lifted further by 6 feet i.e., 55 feet above sill level and facilitated the discharge to the tune of 14.5 lakh cusec

• after observing for one hour it was noticed that the water level in the reservoir did not rise and the water level at the bottom of T-Beam was reduced by 2 feet and that the vibrations in the civil structure and gate ropes were minimum.

• the ropes of Gate No 4 on right side were in snapped position and it was decided not to further operate this gate.
• engineers succeeded in opening the 12th gate of the dam (i.e., Gate No 1) at 1 pm on October 3 (after 20 years) allowing 14.8 lakh cusec outflow from the dam.

Post flood status of the dam

• dam did not suffer any major structural damage.
• operation of the end gates resulted in significant erosions to both the right and left flanks.
Spillway and non over flow

- dam withstood the unprecedented floods.
- bearings of the road bridge were intact and no displacement or damage was apparent.
- dam had tilted by 4mm on October 3.
- tilt reached a maximum of 8.8 mm on October 8.
- each square metre of the dam had to withstand the uplift pressure of over 170 tonnes while the permitted level is only 143 tonnes.
Gates

• there were problems in proper functioning of the turn buckles, noise in the gear worms, loosening and entangling of wire ropes etc.

Plunge Pool

• deep scours could have taken place in plunge pool,
• exact nature of changes that have taken place have to be first known.
• bottlenecks in carrying out any work downstream are: limited time available for works, extreme difficult terrain in gaining access to the work area, considerable depth of water and finally the exorbitant cost of such works.
• bed contours of the downstream area are plotted after taking levels by soundings and super imposed over the last year’s contours to know the changes.
• need for any immediate or long term measures is being assessed

Erosion of the right and left bank hill slopes
• operation of the end gates has resulted in significant erosions to both the right and left flanks.
• this is not an unexpected feature, as these have been anticipated and confirmed through model studies earlier. It is for the same reason that restrictions were placed on opening the end gates in vents 1 and 12.
• the gate in vent no 1 though opened had discharged only the spilled water over the stop log gates.
• erosion took place mainly on account of the flare of the ski jump jet due to flow in vent no 2. Similar is the case with the vent 12.

**Left flank**

• left flank hill slope has attained a near vertical slope above the water surface;
• profile below the water surface is to be verified after the downstream water levels go down.

**Right flank**

• three cavities were formed on the right bank as a result of the impingement of the ski jump jet on the flank.
• these are located at about 1000 feet downstream of the reference line and are at an elevation of about +610.00 feet.
• inter bedded sequence of quartzite and shale is exposed downstream of the bucket between vent 12 and the upstream of the right bank power house.
• sedimentary sequence is intersected by two sets of moderately close to widely spaced joints and near horizontal bedding planes.
• on account of the opening of gate 12, huge blocks of shale and quartzite forming the right bank was removed damaging the road leading to the river bed.
• flare of the water jet beyond the bucket resulted in the removal of thinly bedded shale/quartzite sequence resulting in the formation of cavities on the right bank.
• these pockets located away from the dam and pose no risk to the dam and will not have any impact on the stability of the dam.
• the sizes of openings are not of such nature as to bring down the overburden. Back filling with any material would also not be effective.

• as the recurrence of similar flood is unlikely in the near future, it is necessary to keep a watch on the cavities and consider any remedial measures after observance over occurrence of 2 or 3 normal floods.

• the ledge at elevation of +600.00 feet and below has the possibility of further erosion in the future floods, as the area is opposite to vents 10 and 11. This is also just upstream of the power house structure.

• the CWC has earlier recommended anchors, underpinning the over hangs with concrete and also laying concrete in suitable steps as a remedial measure.
Studies and surveys to be carried out

- to assess the extent of erosion of the plunge pool area
- identifying the probable locations for installation of rain gauges in the catchment area upstream of Srisailam dam but downstream of Jurala and Sunkesula projects,
- review record of vibrations during the flood period (from 30.09.2009 to 06.10.2009) and also from the strong motion accelerographs erected in blocks 12 and 18,
- stability analysis of spillway section and non overflow section for the conditions obtained during the floods and comparing them with the design assumptions,
- seepage studies covering the same period and compare the uplift pressures recorded with that of the design parameters,
- assess the status of the drainage holes, Review of all other instrumentation data during the flood period,
• hydrographic surveys to assess the extent of loss of storage after the floods,
• flood routing studies with different pre depletion levels of reservoirs at Srisailam and NSP for different flood magnitudes,
• post flood detailed assessment by the Geological Survey of India of the geological features of both the hill slopes in the areas of anticipated ski jump jet areas.

Short term works to be carried out
• repairs to gates such as replacement of turn buckles, wire ropes, gear worms and other electrical items,
• readying the zero bay area and shifting the stop log elements existing in vent no 1 to this bay,
• acquisition of one new set of stop log elements,
• acquisition of 60 T gantry crane,
• rock bolting of the eroded area downstream of vents 10 to 12 on the right flank.
Long term works to be carried out

- 3-D model studies,
- protection works to the plunge pool to be identified and executed in stages,
- erection of automatic rain gauges in the catchment area downstream of Jurala and Sunkesula projects for real time data transfer to the site,
- evolving comprehensive guide lines for operation of Srisailam and NSP reservoirs for pre and post Pulichintala dam completion,
- assess the latest storage capacities of both the NSP and Srisailam reservoirs,
- conduct flood routing studies for both the reservoirs taking into account the restraints such as inoperative gates at Srisailam dam,
- limiting the upstream water levels to FRL only at Nagarjunasagar,
• the possibility of encroachment into free board at Srisailam dam, the limitation of channel capacity downstream of Prakasam barrage and evolve guide lines for operation of the reservoirs, to consider the scenario after the completion of the Pulichintala dam and evolve guide lines for the post Pulichintala dam completion period

Srisailam right bank powerhouse and Srisailam left bank powerhouse had been affected due to floods

• Srisailam right bank powerhouse
• Precautionary measures taken: all seven units were stopped at 19:00 hrs on 02-10-2009 to protect the powerhouse and personnel working in it. power Supply to the powerhouse was cut off anticipating entry of water and station made electrically dead.
water entered into the powerhouse from river side over the flood protection wall inundating it by 15:00 hrs on 03-10-2009 as the tail water level rose to a peak of +646.2 feet above the flood protection wall constructed up to +640 feet.

- **Cost of restoration:**
  - draft tube gantry crane and gates - Rs 3.0 crore
  - flood protection wall, approach road retaining wall, TRC structure, etc., - Rs 12.0 crore
  - E& M equipment, panels etc., - Rs 80.0 crore
  - BHEL (Bharat Heavy Electricals Limited) services - Rs 10.0 crore
  - rectification of Gen. Transformers - Rs 3.0 crore
  - LT Boards, compressors, etc., - Rs 10.0 crore
  - other miscellaneous works - Rs 1.35 crore
  - **total** - Rs 119.35 crore
• **Synchronization:**
  1st unit by 05-12-2009.
  Balance 6 units by January 2010 at an interval of 10 days.

• **Left Bank Powerhouse**

• Precautionary measures taken:
  All Six units were stopped at 19:00 hrs. on 02.10.2009.
  Entry point of inclined adit tunnel was plugged with cement concrete to prevent entry of water.
  The Crown Adit to powerhouse was plugged to avoid ingress of water into powerhouse.
  Thus major damages to the powerhouse were averted by providing concrete bunds at upstream and downstream sides of the river.
• **Damages**

tail race surge cavern experienced heavy thrust of water and continuous splashing resulted in complete flooding of surge cavern.
draft tube gates of six generating units damaged. civil structures of DG set and ventilation equipment building were damaged.
approach road to the surge cavern was eroded severely.
- **Cost of rectification:**
  
  plugging of inclined adit and crown adit tunnels, clearing of boulders, construction of flood protection wall, strengthening of DG set building footings, etc - Rs. 3.5 crore.
  
  construction of flood protection wall and retaining wall; re-laying of approach roads - Rs.12.0 crore
  
  Rectification works of draft tube gates - Rs. 3.5 crore
  
  Cost of new draft tube gates for 2 units - Rs. 1.0 crore
  
  Total - Rs.20.0 crore
• **Total cost of restoration of both the power houses**
  Srisailam right bank powerhouse - Rs. 119.35 crore
  Srisailam left bank powerhouse   - Rs.  20.00 crore
  Total                            - Rs. 139.35 crore