The Sardar Sarovar Project – India

This note has been prepared in response to recent requests for information about Sardar Sarovar Project. The note explains the institutional groundwork that permitted the undertaking and the overall purposes and concepts guiding its design and plan for operation and maintenance.


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Synopsis

The key features of the Sardar Sarovar project are;

(a) The political agreement for sharing the waters of the Narmada Basin for all time between the States of Gujarat, Madhya Pradesh and Maharashtra which took more that 20 years to negotiate;

(b) The concept and design of a ‘controlled-volume’ water conveyance and distribution system structured for traditional irrigation concepts which provides ample flexibility for the political, social and economic needs in the municipal, industrial and agricultural sectors for the next 50 years.

(c) The Institutional arrangements which clearly defined the duties and responsibilities the Government of Gujarat and at each level of the state corporation that will manage the most complex program in the Indian water resources sector; and

After 20 years of construction water is about to start flowing into the main canal.
Narmada River Basin Agreement and Opportunities for Gujarat

The Narmada River Development – Gujarat (aka Sardar Sarovar) in the State of Gujarat, India is one of the largest undertakings of its kind in India, indeed, in the world. To better understand its complexity, this summary outlines the evolution of the multi-state basin development plan and the purpose and formulation of the Gujarat’s Sardar Sarovar Water and Drainage Project (SSWD). This massive system is one of two implementation projects to complete the developments within Gujarat. For purposes of design and construction management, the Sardar Sarovar dam and power plant that comprise the water diversion to the supply system were set out as a separate project.

The multi-state Narmada Basin development also includes two major dams in Madhya Pradesh (MP), upstream of Gujarat, and several hundred thousand hectares of additional irrigation by that state’s Narmada Valley Development Authority. But work on these has been postponed.

A Central government Tribunal that began deliberations in the 1960s created the remarkable foundation for Gujarat’s undertaking and those of its neighbors. The Tribunal negotiated an agreement among the basin states on the allocation of basin water, broad rules for basin water operations and cost sharing of key basin facilities.

The Narmada River Basin waters rights were permanently adjudicated. Approximately one-third of the basin runoff was allocated to Gujarat, two-thirds to Madhya Pradesh (MP) and nominal amounts to Maharashtra and Rajasthan. (Rajasthan is not a riparian nor is it treated as such.) Water was also set aside for environmental flow to the ocean.

A permanent basin allocation is remarkable in India for several reasons. There will be no reconsideration of the riparians’ rights at fifty-year intervals as stipulated for most interstate basins in India. This allows the Narmada basin states to independently plan their long-term development and decide on the nature and timing of their undertakings. No premature or costly over-construction is required in order to retain water rights. And hydrological data on the river now can be openly and cooperatively shared among the riparians.
The three key dams and reservoirs within the states of Gujarat and Madhya Pradesh will be jointly owned and paid for by the states in proportion to their adjudicated basin water quantities. The associated storage volumes are at the disposal of the individual owners. Thus, the limited number of significant basin reservoir sites and the operation of the combined facilities can be utilized to yield maximum benefits to all signatories of the agreement. Hydro-electric generation at the dams are to be treated under similar rules.

Lastly, the permanent allocations ensure each state’s future supply and can underpin financing of the associated projects. This is an extremely important result, because the states will have to bear the burden of the costs and secure the majority of the financing.

A Narmada River Basin Authority, governed by a board of directors representing the four states and Central government supported by a small staff, operates the basin hydromet system and oversees activities of the members for the sole purpose of ensuring compliance with the agreement and resolving any disputes. The Authority has no operating control.

**Framework for the Gujarat’s Water and Drainage Project**

For Gujarat, the Agreement allows it to invest billions of dollars US in the vast facilities necessary to accelerate the provision of services to its rapidly growing urban centers and regional cities and to irrigate 1.9 million hectares. India / Gujarat borrowed from the World Bank to fund the early planning and design of the facilities and the initial contracts on the SSWD and the dam and power plant. Subsequently, the Narmada Niggam (NN), the state owned corporation created to build, own and operate the project, issued project general obligation bonds for financing the next phases of the undertaking. The initial value of bonds sold, a majority to domestic investors, in the 1990s exceeded one-half billion US dollars.

The services will include water supply, storm drainage, and an improved village-to-market road network and groundwater control in the coastal lands. Gujarat can, with confidence, meet the critically important reliability of the water service by adopting advanced design concepts. A backbone supply system will provide bulk supply to municipal and industrial customers and is structured at a level to serve a diverse changing
agriculture on into the future. The surface storm drainage system in the rural areas follows conventional design. Groundwater control and conjunctive utilization necessitate a refined ground water pumping network.

The main canal extends from the SS reservoir on the Narmada River to the Rajasthan border with gravity service to most of the project area. One exception is a series of small lifts for tributary service to the Saurastra area. Small hydro stations were proposed for several distributaries to generate electricity and avoid the construction of energy dissipation structures.

The main conveyance system was designed for “controlled-volume” operation (a concept devised for the California Aqueduct and successfully operated since the early 1970s). Twenty-four hour monitoring and control with the capability of simultaneous gate operations at the appropriately spaced canal check structures and branch pump units throughout the system allows ‘canal’ water to be stored or released to accommodate mismatching changes in flows up to a full shutdown of the canals during maximum discharge. This design meets several additional objectives. Shutdown can be made immediately to isolate a breach of an embankment or emergency at an above-surface river crossings or pumping plant (usually an interruption of the electrical system). Uncontrolled drawdown due to a breach of medium to large sized canals, as found on this project, can cause immense costs for repair and prolonged remedial work. The operating scheme precludes the need for localized reservoir storages within the system or wasteways – costly and only marginally effective.

Ahmadabad, Vadodara, Bhavnagar, Mamnagar and Gandinagar the largest cities with several million inhabitants and the industrial centers of the state will be major customers of the SSWD. The urban centers will maintain and operate their existing surface and groundwater supply works to help ensure service during any interruptions in the SSWD. However, these and other cities will increasingly rely upon the SSWD as their primary source of water. Many smaller cities, particularly in the northern areas of the state and on the Saurashtra peninsula, have lacked adequate supply for decades and are highly vulnerable to droughts.
Agriculture is a major component of Gujarat’s economy and to increase rural income, the irrigation system should readily allow moving away from the currently rigid cultivation of field crops. The many expanding urban areas coupled with changing diets will increase demands for vegetables, poultry, dairy, feed crops and even tree/vine crops. Root depth, time of planting and crop growth period are three variables that call for flexibility in deliveries to service areas if communities wish to specialize in a market -- or even make best use of new crop varieties -- in order to increase income. The adopted operating capability greatly improves service reliability and allows a significant degree of service flexibility to the farmers.

Climate and soils in the SSWD do not vary significantly relative to the adopted size of the service areas (SA) in the range of 200 - 500 ha. The choice of SA boundaries was dependent on six parameters; (a) soils; (b) climate; (c) existing social (village) structure; (d) future agricultural market opportunities; (e) timely response to emergency failures and localized rain storms; and (f) capital and O&M costs.

The criteria (c), (d), (e) and (f), proved to dominate the configuration of SAs and the layout of the associated facilities. Community cohesion, community cooperation, the local focus of agriculture and the available service flexibility favored the community as the SA unit. This was judged critical for application of SA operations rules, enforcement of acceptable behavior and scheduling of deliveries. It allows farmers within a community as a group or independently to specialize in crops and equipment to best meet their particular soils, climate and markets. (Every farmer within an individual SA, however, will have the same service.) Market opportunities are already changing, with villages even at some distance from major markets moving towards vegetables and even greenhouse production. The adopted operational capability also allows isolating areas under local heavy storm events with resulting water savings and reduced damages.

The capital and cost of the system and its O&M are affected by the level at which the system becomes ‘structured’. Above the structured level the system is regulated, below the structured level (on SSWD set at the SA) the system is proportional pre-scheduled flow. However, extensive experience with similar advanced systems confirms that the overall costs
do not differ greatly considering the savings in structures, staff and water. Indeed, substantial savings are evident on large bulk systems.

A review of the Narmada river water quality, the surface soils, area geology and characteristics of existing wells throughout the project area confirmed that good groundwater quality would maintain with only relatively little seepage to the ocean for salinity control. Thus, it was agreed that conjunctive management of the water resources – surface and ground waters – effected by an appropriate system operations policy and facilities -- would be fundamental principles for designing the project.

Groundwater will be developed to the full extent in order to control water loss by seepage to the ocean. Given the quantity of surface water introduced into the project area, the resulting increased recharge will make groundwater a major additional supply though recycling. Cities, villages and farmers will be encouraged to develop groundwater. (For this reason, surface water allocations to SAs in areas with utilizable groundwater will not be adequate for full cropping of a farmer’s land.) The NN will construct a well network to intercept any remaining excess, particularly under lands in the zone adjacent to the ocean. The NN network will discharge into the surface conveyance system and the water will become part of the allocated ‘surface’ water.

Project water supply will be allocated to lands uniformly within each O&M ‘Division’ (there will be about fifteen) – but will differ among divisions as determined by climate, utilizable precipitation, soils and potential for groundwater supply. System capacity will meet reliable rainfall-adjusted crop water demand on a percent of the farmers’ CCA three years out of four. “Crop water demand” was determined for a mix of crops for the purpose of setting delivery capacity. Actual crop selection will be decided by the farmers, though sugar cane and rice will be discouraged for dry season production.

Annually, NN will estimate water availability and project allotments and the total annual quantity that will be allocated to each SA according to set criteria. The initial SSWD operations will supply, during every delivery period to an SA, a constant discharge for seven days. The SA decides on the date it wishes to commence its season’s services, the number of deliveries per season, and thereby, also the volume of the individual deliveries (that will total its annual allotment) and the starting date of
each delivery period. Minor modifications to the bulk delivery operations may be needed to refine local system schedules. SA flows will be rotated among member farmers in a manner to effect equitable allocation of the supply to each member.

The project provides for storm drainage systems down to the 40 ha level. This will be sized to remove storm runoff caused by a three-day storm at a five-year frequency, within a time period that will prevent crop damage. A road network to the village level will be constructed. This will be independent of all canal roads for reason of safety and work access.

The O&M organization and detailed features were prepared on the basis of the design operations to ensure timely, efficient and effective services. The requirement of a highly reliable supply to the tens of millions urban inhabitants and the areas industries plays an important criteria for the system design as mentioned. But the required reliability of urban supplies and more sophisticated agriculture, also demands the formulation and immediate installation of an operation and maintenance capability at full strength from the very onset of services to a given area.

The SSWD project O&M organizational structure was devised at the same time as the design concept and criteria for the conveyance, distribution and drainage system and categories of customers were defined. This parallel action is too often neglected with extremely costly consequences that may be difficult to rectify once in place – the history in too many countries. (The adopted plan reflects experience gained in Iran, California and elsewhere.)

Six levels were created setting out the functions and responsibilities of each. Detailed listings for each level were made of staff makeup, a full complement of equipment and the size of buildings and equipment yard to fulfill the assigned functions. A diagram describes the partner ‘farmer organization’ at each of the six levels, their composition, functions and inter-relationships. (It was strongly recommended that some buildings for the higher level units be constructed early to serve as temporary offices for the NN construction organization and the backbone staff of the O&M units as they prepare for the transfer from construction to O&M and commence initial organizational work with the farmers.)
The Service Area Irrigation Committee (SAIC) of farmers, with chak committees, are to organize to carry our all O&M functions at that SA level. The chairman will be the contact for the NN O&M units. Above that level, all O&M responsibilities reside with the NN organization.

A ‘Block’ headed by a foreman with three laborers, will maintain the NN irrigation and drainage facilities within its assigned 5000 ha area – about ten SAs. It will have no operations responsibilities.

A ‘District’ headed by a ‘Water Master’ (WM) is the lowest administrative unit, and is the entity that directly serves the SAs within five blocks -- an area of 25,000 ha. and 50 turnouts. The WM will spend considerable time working with SAIC chairmen. There will be an assistant water master and three canal operators and other staff (with additional well operators - maintenance staff as warranted). The deputy WM will also monitor O&M and have days dedicated for communications with SAs to promptly resolve any questions. Staff, meeting, training, storage and maintenance facilities would match its specified responsibilities.

A water distribution ‘Division’ will usually consist of about five Districts or about 125,000 ha. This will be the principle action line agency of NN and be comparable to an independent irrigation project. It will have day-to-day responsibility of the O&M performance within its boundary and all related annual and long range planning, revenues and budgets. The larger maintenance equipment will be housed at this level. Staffing will be tailored to the functions. O&M evaluation, staff and SAID training as well as management meetings will be significant activities. (A copy of the function statement of a water distribution Division and a water distribution Region together with the staffing and equipment list for a water distribution Division may be found in the Annex at end of this summary.)

Total staff from managers to clerical at the water distribution Division headquarters would number 135. Its five districts would have 15 each and its 25 blocks would have four each. The grand total under division management would be about 295.

A Region will oversee four water distribution ‘divisions’. This unit will have a very small, but very experienced senior level staff which together with a large records section, would total 35. The unit will serve as on-site
offices of the NN project office and coordinate activities among water distribution Divisions and with the Project Office; provide oversight and quality control of services and O&M; and review and approve any non-budget expenditures.

The dam and power plant Division will be responsible for the O&M of the associated facilities. Daily, weekly and monthly water operations will be conducted under criteria and policies of the Project Office. It will release water to the Main Canal Head pool and river in compliance with the agreed schedule established in coordination with the main canal Division and the distribution Divisions.

The main canal Division will be responsible for O&M of the associated facilities and will conduct water operations under the same provisions and procedures as the dam and power plant Division. Daily, weekly and monthly schedules will be routed to meet current delivery information. Releases to the branch turnouts serving the distribution Divisions within the Regions will be in accordance with schedules and modifications received directly from the distributing Divisions.

The individual Divisions – dam, main canal and distributing divisions in the SSWD -- will have full responsibility and full capability for the 24-hour remote monitoring and operation of all control structures and canal pumping plants within their respective jurisdiction. There will be continuous communications among the water operations centers of all Divisions with continuous status updates among the main canal Division and water distribution Divisions.

All Division offices will have a monitoring and control center covering the Division’s facilities. A set of functional specifications were prepared for the ‘monitoring and control system’ including field and office equipment capabilities, communications, pre-formulated programs for application under normal and potential emergencies, and system backup. The component features of control centers were detailed.

The Project Office will report to the NN administrator. It will forecast NN’s annual yields some months prior to initiating yearly service and finalize annual allotments once firm yield is determined. It will ensure coordination and application of NN O&M policies and activities of the SSWD Regions, the Main Canal Division, and the Dam and Power Plant
Division. The Project Office will execute responsibilities for relations with neighboring states and Central government as delegated by the NN administrator.

The technical construction contract provisions were a blend of Indian standards and provisions used on the California Aqueduct project. The adopted provisions greatly tightened control of work including foundation exploration, site preparation, embankment construction, maintenance of foundation moisture at the time of placing canal lining and concrete mix, placement and curing. The basic configuration and construction details of concrete structures were similarly modified.

Customer satisfaction from the very onset of service was judged to be an important SSWD objective. The Project design layout and contract packaging focused on the objectives of reducing costs and providing all ‘services’ within an area upon completion of work in that area. The period of disruption to communities was to be held to a minimum.

Accordingly, the delivery and distribution contracts were awarded commencing in Division I. Contracts packages fell into two general categories. One was composed of major conveyances (supply and drainage) and the second of the complete package of all facilities at the lower level. Thus, all earthwork for delivery, storm drainage and farm-to-market roads and all structures were awarded as a package to one contractor. Savings in costs were evident. But more important, right-of-way acquisition was reduced and excavation and borrow were balanced better while the disturbance of the agricultural lands were minimized.

Though not a part of the Project, meetings were held to move the state of Gujarat’s highway department to locate major highway alignments, set forth the associated geometry in advance of the finalizing SSWP layout and contracts. The coordination of the department’s plans and the Project plans would offer substantial savings and improve Project and state transportation systems. (This would have been much more effective if initiated well before the Project final design commenced as was demonstrated in developments in other countries.)

Annex (3pgs) begins next page.
25. **Division.** The next larger subdivision of the project above the district is the division that would normally consist of five districts and would therefore encompass 125,000 ha. About 250 SA turnouts would be served within a division. Each division would be substantially larger in regards to the area served and its responsibilities than most existing irrigation projects today; hence, essentially all day-to-day O&M decisions on the SSP would be centered within the division and its units.

26. As stated, the division would be the principal action line agency of the project and would be the largest project unit carrying out any primary O&M functions. The division would be headed by a division manager, with assistant managers for administration, personnel and training, operations, and maintenance and construction, supported by two special units. Depending on the extent of differences in equipment and other maintenance requirements between major canals and large drains and the smaller branches and distributaries, it may be appropriate to include a "major canal" maintenance staff and equipment group in those divisions having responsibility for such facilities.

27. Each division would secure and disburse its own funds subject to budget review and approval by the region. Regional approval would be required for all averages or nonbudget item expenditures. An important unit of the division would be an evaluation, planning, and budget unit (EPBU) to be headed by a senior person with at least 15 years experience in operations and maintenance. This person could be an experienced farmer, water master, or an assistant division manager—operations, maintenance, and construction, or administration. The unit would be staffed by three persons with broad and objective backgrounds in water project management. The principle function of the EPBU would be to review, evaluate, plan, and then budget the next year's activities after consultation with farmer and district representatives. This unit would report directly to the division manager, with copies of all reports and recommendations being forwarded directly to the regional EPBU.

28. **Region.** The irrigation project would be divided into four regions, as shown on Figure 3. Region I would constitute the initial phase of project development. The regions would average about 500,000 ha in area, and would be headed by a regional director. The region would essentially provide staff support to the divisions and facilitate and ensure coordination among the divisions. Collection and presentation of information to the project office for use in projectwide water allocation would be a prime responsibility of the region. Indeed the four regional offices could be viewed as on-site subdivisions of the project office functioning as the coordinating link between the project office and the large complex divisions. This should be kept in mind when setting relative levels and compensation, which must be commensurate with responsibilities, not just positions on a chart. No "line" operation, maintenance, or construction functions would be carried out at the regional level.

29. The staff would be very limited in size but will be organized to correspond somewhat to the division, in that there would be assistant regional directors for administration, O&M, and construction. These would deal with policy and broad administrative matters to provide general coordination and, hence, would have no assistants.

30. In addition, an assistant regional director would head the regional evaluation, planning, and budget unit. This regional EPBU, and its lower-level counterparts down to the district canal operators comprise the "quality assurance" arm of the entire project. With this unit functioning as planned, both the farmer's well-being and that of the project would be assured—reports from the lower offices would be correct, complete, and timely—and top management at all levels can be confident of results and made aware of necessary actions and changes in a timely fashion.
(c) **Division - Irrigation**

(i) **Staffing**

division manager
1 receptionist
1 secretary
2 computer operator/word processors
1 clerk typist

head, evaluation, planning, and budget unit
3 senior assistants (see text)

assistant manager, administration - finance (disbursements)
1 + 2 audit and cost accounting
1 + 3 water assessments
1 + 2 payroll
1 + 4 collections and financing
1 + 2 purchasing - stock control
1 + 2 computer services, programming
1 + 1 communications clerks

assistant manager, personnel and training
1 personnel
1 training
3 clerk typists

assistant manager, operations
2 hydrologists/water routing
1 civil drainage engineer or technician
3 crop and water records clerks (1 senior, 2 junior)
3 canal operators (major canals)
(These could be at the district level)
2 clerk typists
2 computer operators

Note: Divisions along the Saurashtra and Kutch branches in Region III will also require pumping plant and power plant operators and maintenance personnel—use four operators and two maintenance personnel per plant plus 1 in rotation to allow for absences.

assistant manager, maintenance and construction
1 secretary
1 clerk typist

chief, equipment maintenance section
2 clerk typists
1 foreman, shop - heavy equipment 2 mechanics
1 foreman, shop - light equipment 2 mechanics
1 foreman, shop - pump overhaul and repair, 1 machinist, mechanic, electrician
1 vehicle dispatcher/store keeper
maintenance foreman
5 maintenance men
10 laborers (primary) (these could be in districts
4 heavy equipment operators instead)
6 helpers

chief – construction section (civil engineer)
2 construction crews of 17 persons each (foreman, 3 general
construction, 2 steel and 4 concrete workers, 7 laborers)
2 junior engineers/draftsmen
2 clerk typists

chief, technical services unit (electrical or electronics engineer)
3 computer/radio technicians

(ii) Facilities

Size of buildings and shops required will be dictated by number
of staff. A conference room for each department should
be provided. A large meeting room, equipped with audiovisual
facilities with seating for about 200 people should also be
included. Repair shops, electronics shop, spare parts, supplies
storage, and mess facilities are a few of the additional special
needs to be provided in the complex.

(iii) Equipment

heavy equipment
2 – excavators (hyd. ditch cleaning) (0.9 m³)
(if major canals or channels within division, add
1 w/1.4 m³ capacity, and long-reach capability)
1 – tractor, crawler – 150 hp w/dozer, ripper
2 – tractor, crawler – 100 hp w/dozer, ripper
1 – scraper, 10 m³
2 – loaders rubber tired – 2 m³
1 – roller, rubber tired (vibrating)
1 – roller, sheeps foot
2 – motor graders (Cat 12 or equal)
1 – trailer, lowbed – 30 T
1 – trailer, lowbed – 40 T
1 – truck w/5th wheel to match trailers
1 – fork lift – rubber tired – ground use 8,000 lb cap. 14’ ht
1 – fork lift – rubber tired – ground use 4,000 lb cap. 16’ ht
1 – truck crane – rubber tired – hydraulic 10T, 60’ boom

light equipment
5 – 1/2 ton pickup
3 – 3/4 ton 4 x 4 pickup
4 – dump trucks
3 – automobiles
4 – pumps – low head – 5 – 150 hp
2 – compressors 200 cfm, 360 cfm
4 – generators, portable, 2.5 kw – 12.5 kw
3 – concrete mixers, 1 sack