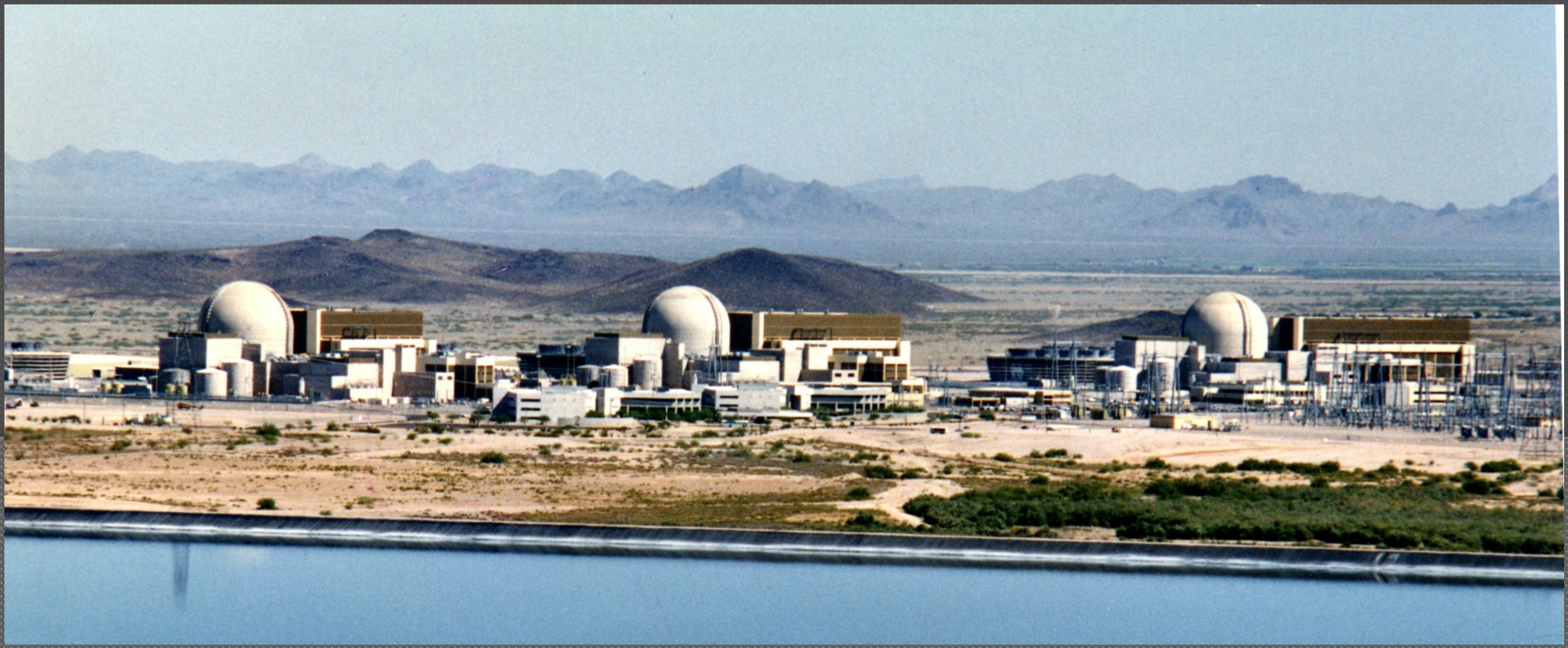
Topical Issues on Infrastructure Development

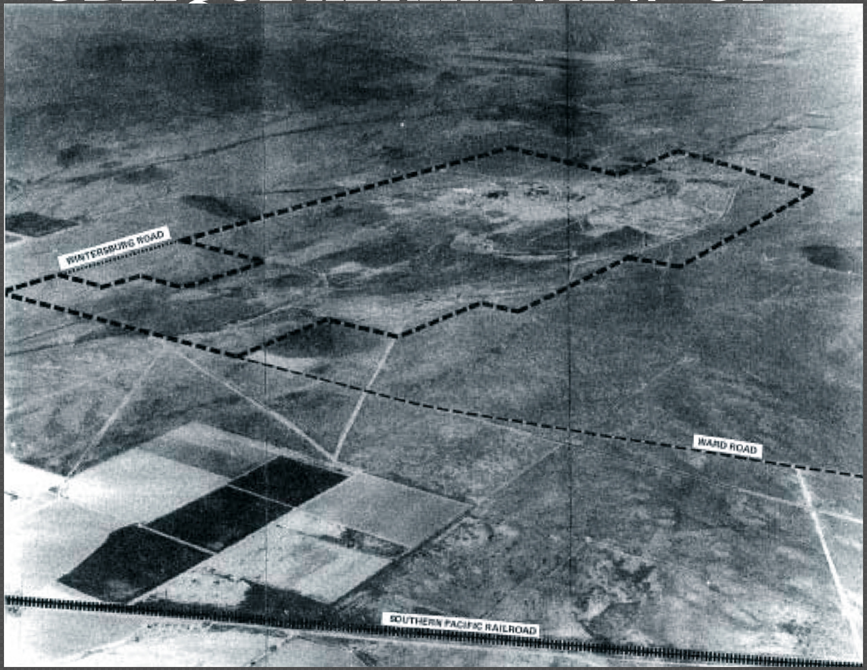
IAEA January 24 - 27 2012



Water resources, utilization experiences at Palo Verde Nuclear Generating Stations

Original / *Current* design

OBLIQUE AERIAL VIEW OF



Core thermal power – 3800 / *3990* Mwth

Total units – 3

Net Electrical output - 1270 / *1346* Mwe

Original size of Reservoir

No. : one / two

Capacity : 33 / *78* [(1)] hectare

Original size of Evaporation pond

No. : one / three

Capacity : 100 / *270* hectare

Ultimate heat sink

No. : two

Type : Seismically design spray ponds

Capacity: 30 days

Type of Cooling tower

No .: 3 / unit

Type : mechanical draft cooling towers

Cooling tower blow down cycle

< 15 / *25* cycles of concentration

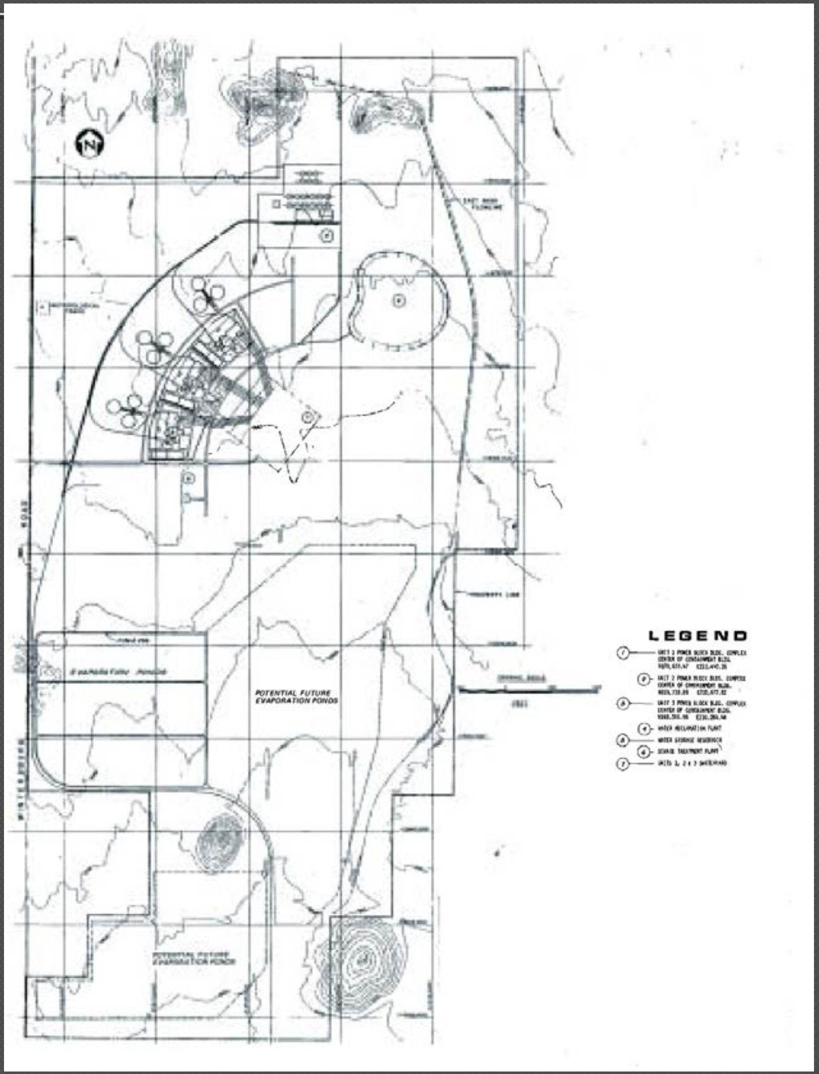
(1) =~ 2.5 E+6 cubic metes

Water Reclamation Facility 1975 / 2012

- **Source of waste Water**: city Phoenix
- **Population** : 1 / *4* million
- **Distance :** 55 Kilometer
- **Influent form Phoenix (1): 150 K liter / min**
- **Production for Plant Tertiary** : 230K / *236* K -liters/ min
- **Reserved inventory** : 7 + / 7 + days at 3 units @100%

- **Onsite wells output:** 6500 / *unchanged* liter/ min

- *(1) Water discharged from city of phoenix 91st Ave Waste Water Treatment plant meets all requirements of Environmental Protections Agency (EPA) for discharge to unrestricted wetland. Maximum effluent flow ~ 500K –litter/min (2010)*



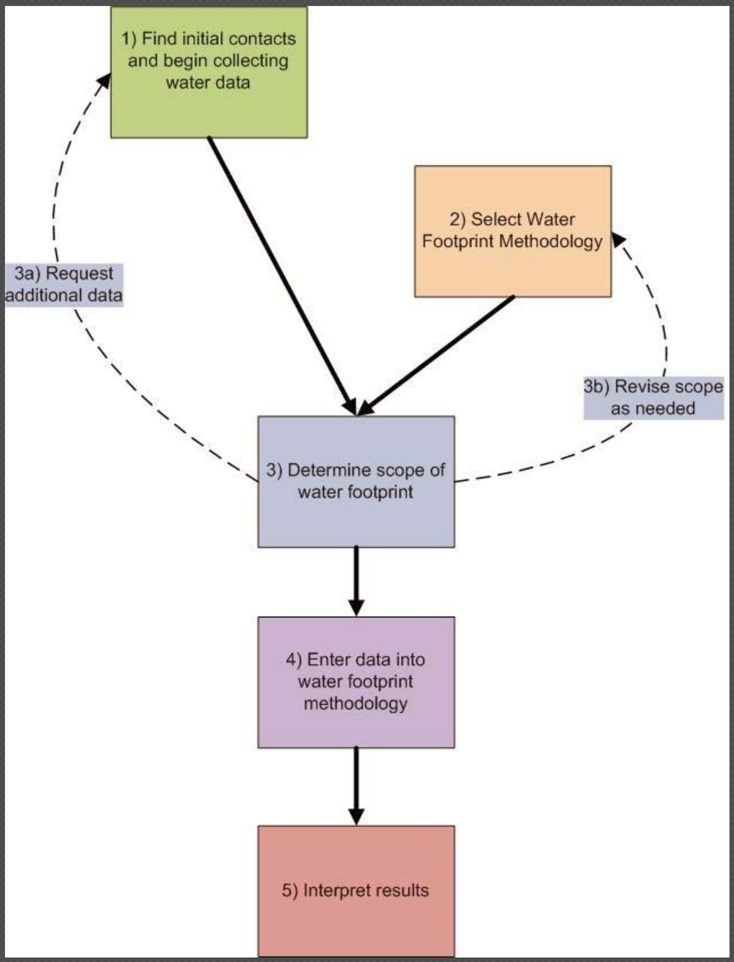
Competition for limited water resource

- Urban population
- Agricultural
- Mining
- Other industry and Power generation.
- Environmental concerns
- Nature (Continuing Drought in US SW)

Distance to permanent sources water

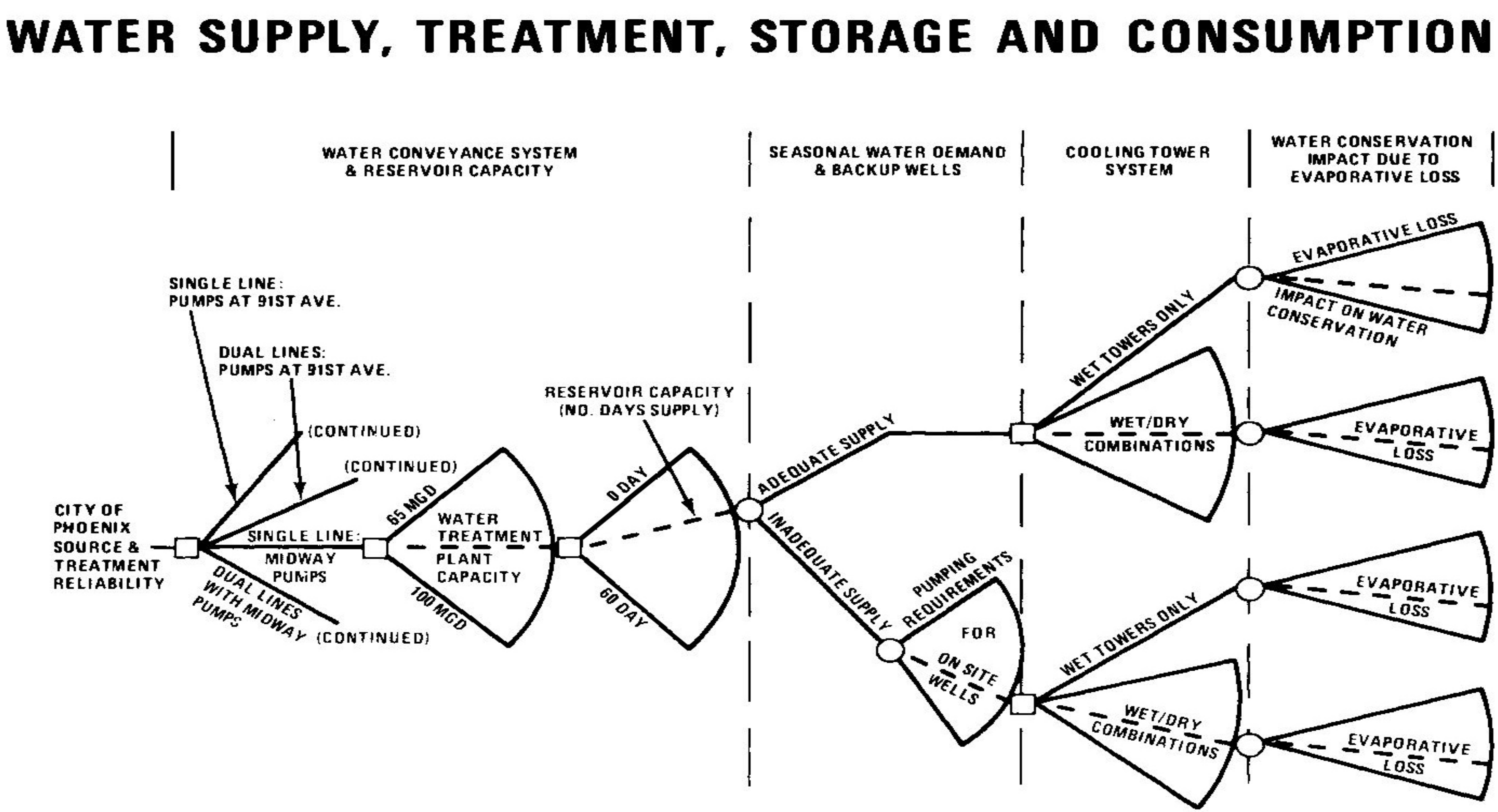
- Gulf of California ~ 500 Km
- Colorado river ~ 250

Strategic location consideration for Palo Verde

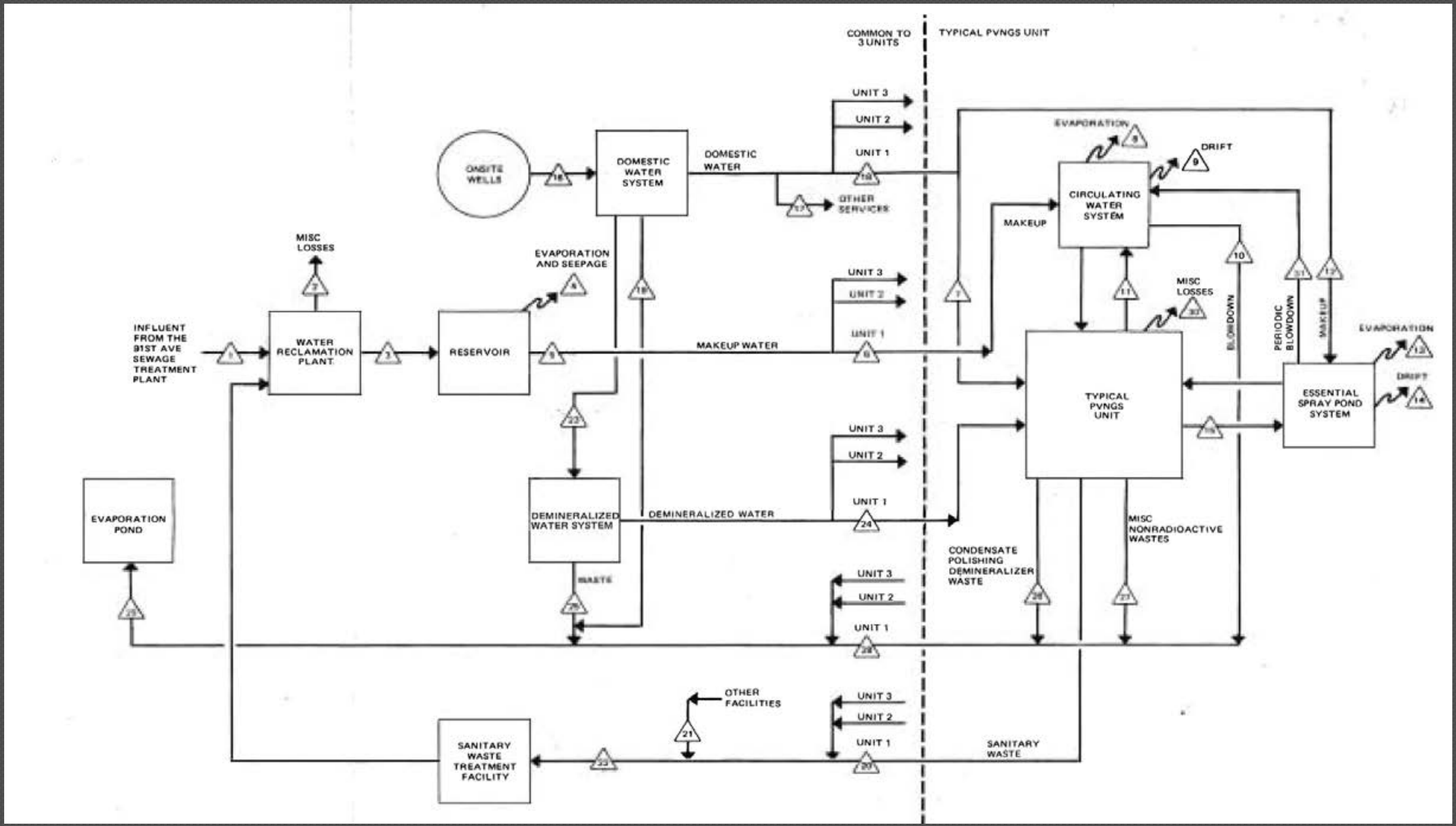


1. Availability water
2. Consumer base
3. Electrical Grid availably
4. Site accessibly
5. Population density

Original Decision tree diagram



Palo Verde NGP Water schematic diagram



Water in the Desert

- Because of its desert location Palo Verde is the only Nuclear Power Facility that uses 100% reclaimed water for cooling.
- Unlike other Nuclear Plants, Palo Verde maintains ‘Zero Discharge’, with no water being discharged to rivers, streams, or oceans.

Water Reclamation Facility (WRF)

- **The Palo Verde Water Reclamation Facility (WRF), is a 341 MLD Tertiary Treatment Plant that reclaims treated secondary effluent from the cities of Phoenix (Scottsdale, Tempe, Mesa, Glendale) and Tolleson.**

Conveyance System

28.5 miles gravity flow with 100 feet elevation drop
8 miles pumped flow with 150 feet elevation increase

PVNGS WRF

Metropolitan Phoenix WWTPs

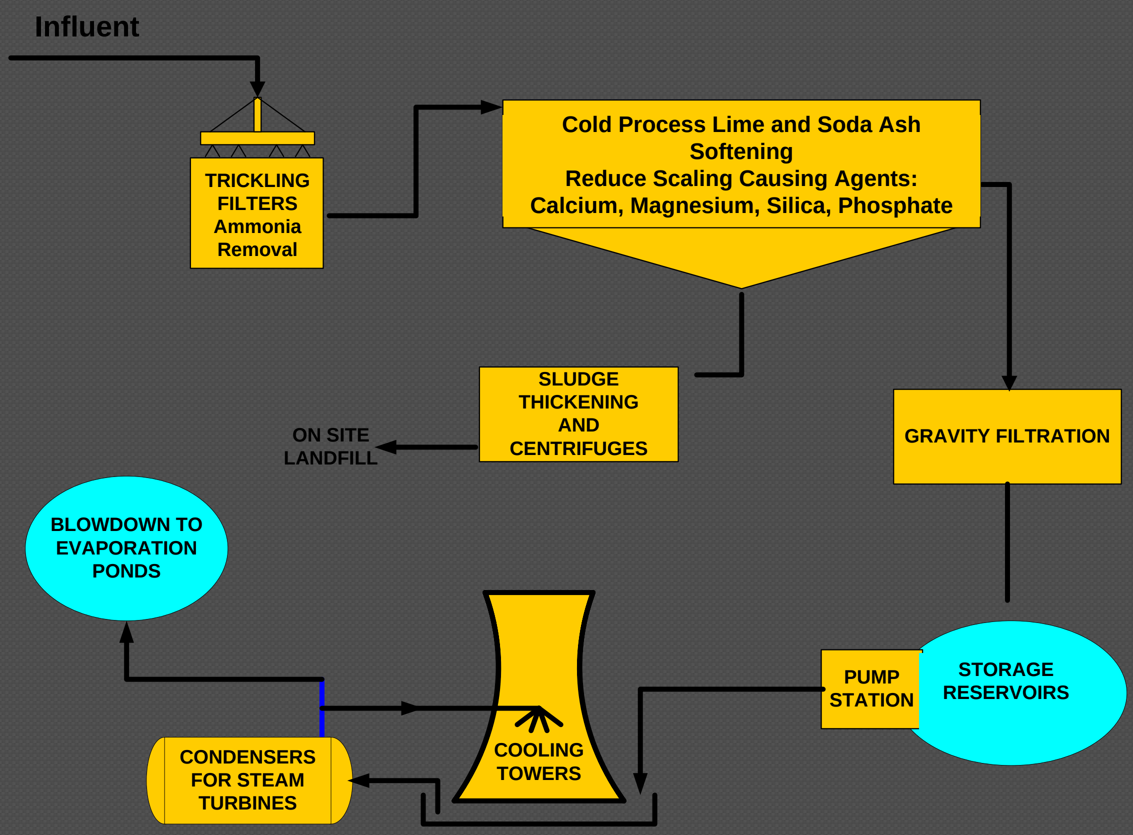
8 miles 66" pressure flow pipeline

Hassayampa Pumping Station

22.5 miles 96" gravity flow pipeline

6 miles 114" gravity flow pipeline for diurnal storage

Processing Waste Water Treatment Plant Effluent (WWTP)



Cooling Water Treatment

- Softening of waste water treatment plant (WWTP) effluent is a necessity. Softening is performed to:
  - Minimize scaling potential
  - Maximize water use
  - Minimize quantity of water required

Scale Forming Constituents (ppm)	Influent Quality	Effluent Quality
Alkalinity (as $CaCO_3$)	189	27
Calcium (as $CaCO_3$)	183	73
Magnesium (as $CaCO_3$)	123	15
Silica	19	3.5
Phosphate	10	< 0.1

18 Hectare Reservoir

32 Hectare Reservoir

Water Use

- Approximate cooling water use per MWH generated – 30 K liter (325 MWH/hectare - meter)
- Cooling water use per year ~ 9.5 kilo hectare-meter, 95E+9 Liters.
- Cooling Water cycles $\geq$ 25, TDS PPM 25,000 – 29,000.
- Cooling water "waste" from blowdown to evaporation ponds per year ~ 370 hectare – meter , 75 % loss to environment

PALO VERDE

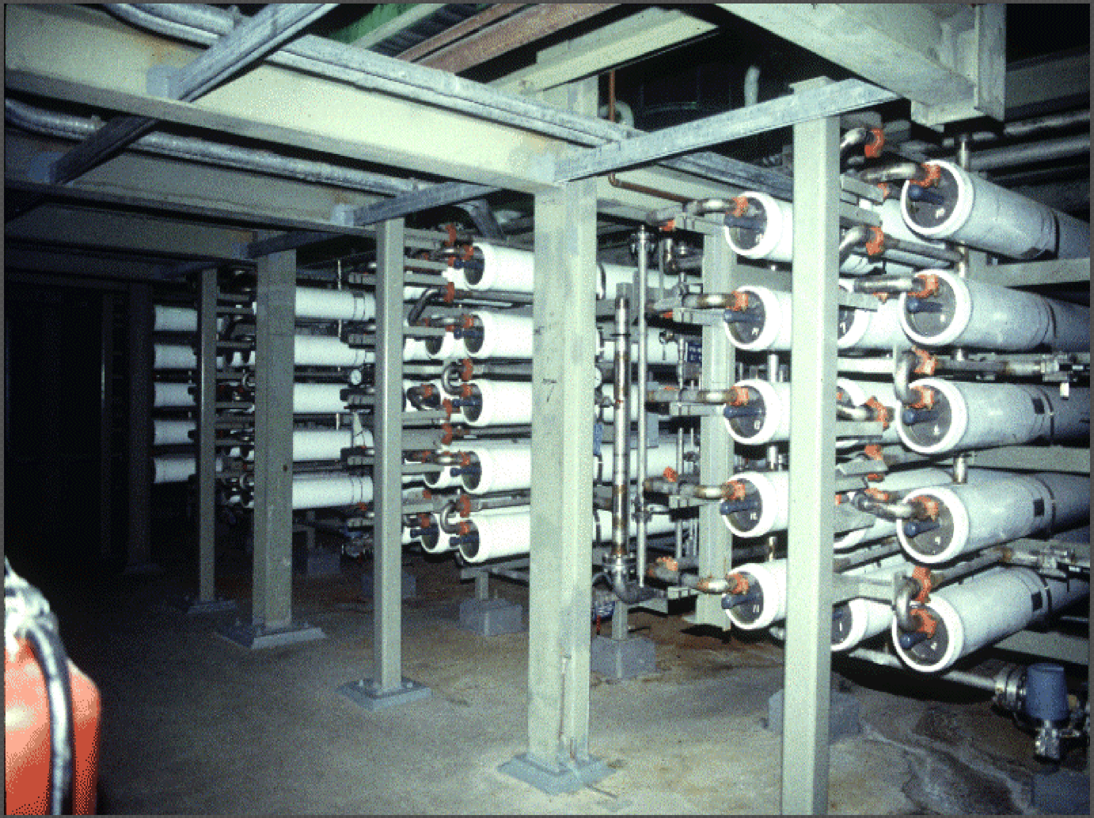
Pre grub of Evap Pond # 3 A

Ancillary WRF Systems

- Domestic Water –
  - Reverse osmosis units fed from on site wells to provide all potable water needs.
- Demineralized Water –
  - Mixed bed demineralizer utilized to meet high purity water requirements for the site.
- Sodium Hypochloride Generation –
  - Electrolytic cells used to produce bleach from brine.

Domestic Water

- Reverse Osmosis units with cellulose acetate membranes are utilized to produce potable water from well water.
- The RO product water is stabilized by filtering through calcium carbonate beds prior to storage for site distribution.
- Sodium hypochloride is also added for sanitation prior to distribution.



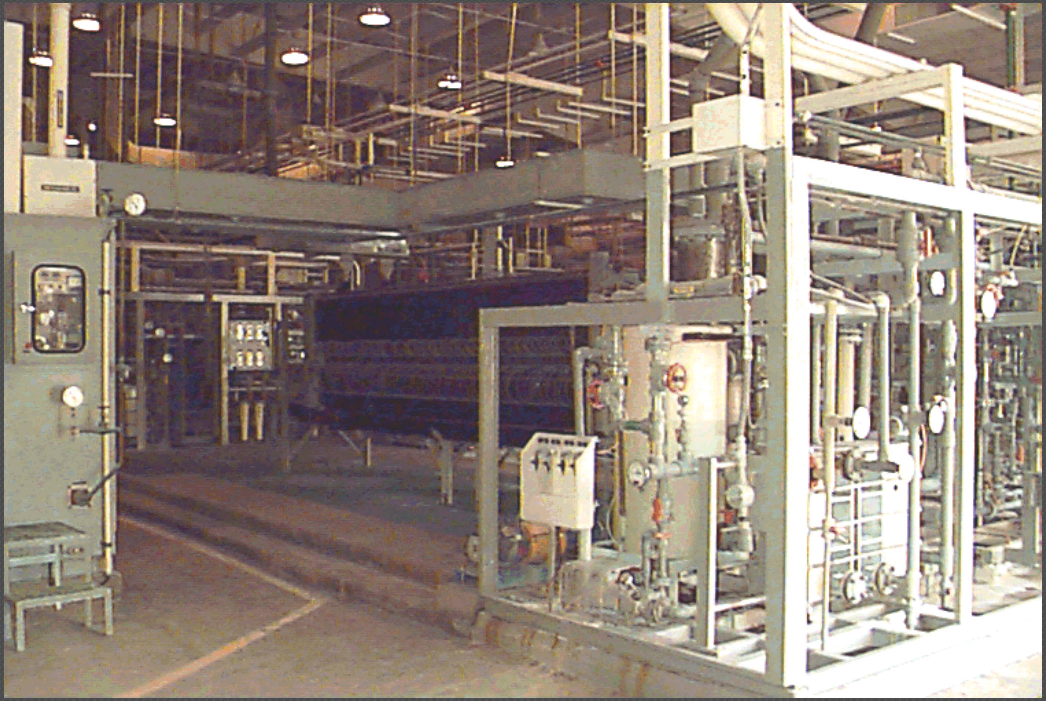
Demineralized Water

- RO product water is the source stream for demineralized water production.

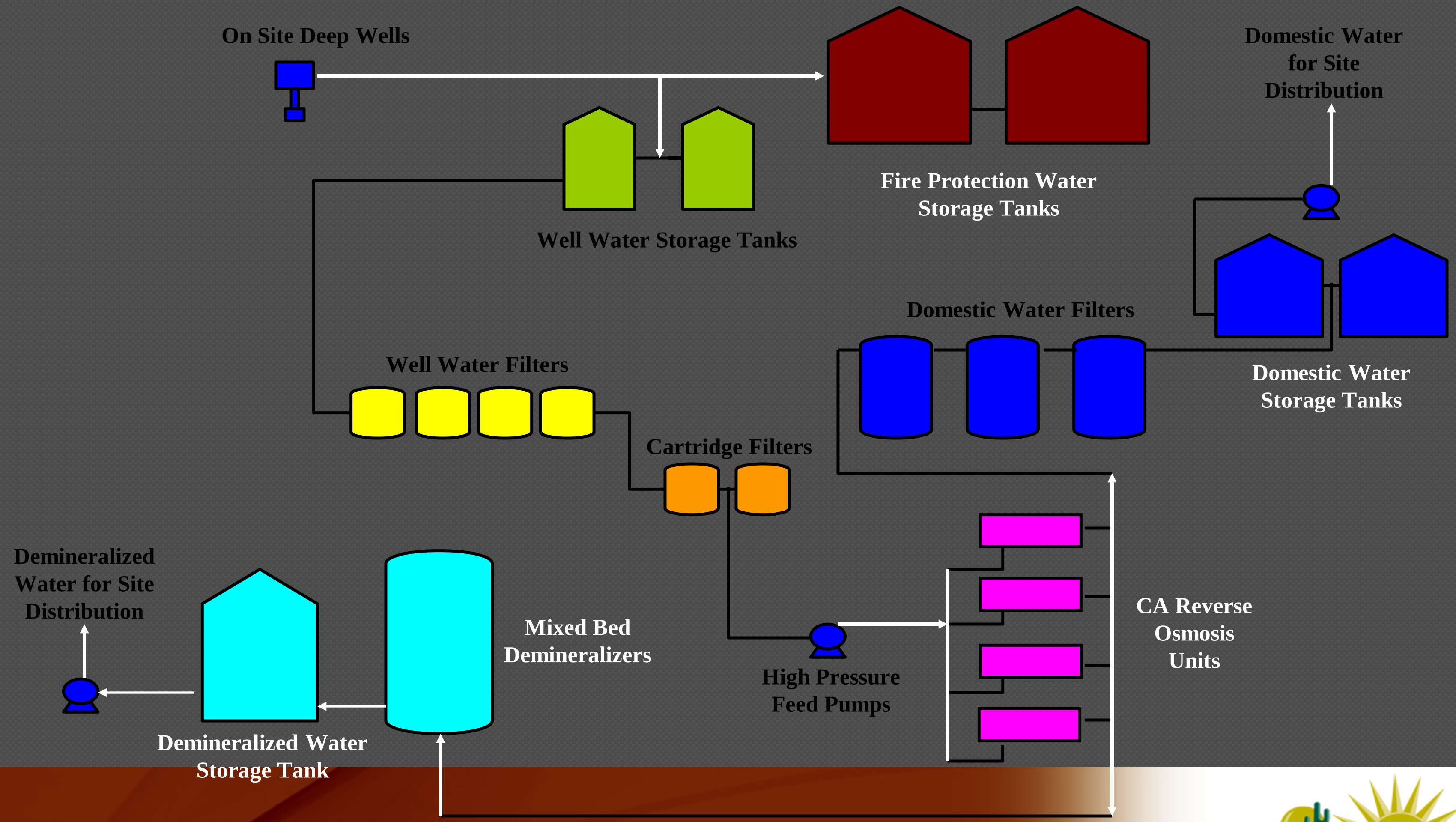
- Product from the mixed bed demineralizers is stored and distributed to the site.

Sodium Hypochloride

- The Hypochloride Generator uses electro dialysis to produce chlorine gas and sodium hydroxide from a saturated salt solution.
- The chlorine gas is diffused through the sodium hydroxide to form a stable sodium hypochloride solution.



Domestic and Demineralized Water Production



Station storage capacity

Demineralized water storage :

No. tanks: one

Total capacity: 1.3 M liter

Domestic water:

No. Tanks: two

Total Capacity: 0.9 M litter

Fire protection water:

No. Tanks: Two

Total Capacity: 3.7 M litter

Secondary quality make up (demin +H-3))

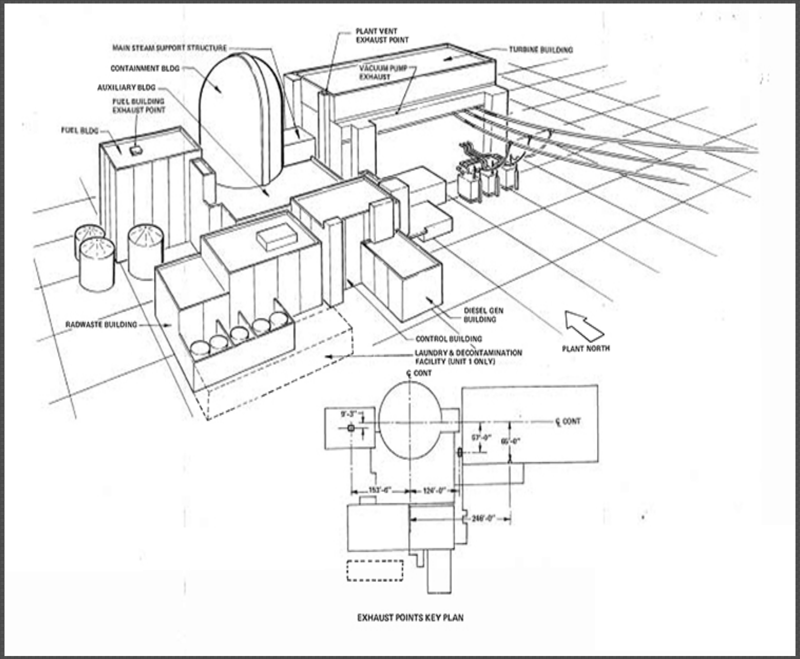
No. tanks : one

Total : 1.9 M liter

Primary quality make up (borated + radioactive)

No. tanks : two

Total : 4.7 M liter



Concentrations of Impurities in Water Sources, ppm

	B	Cl	F	SO_4	SiO_2	Ca	Mg
CST	--	0.1	0.1	0.1	0.0081	--	--
RWT	4000	0.15	0.15	0.15	3	0.08	0.04
Demineralized	--	0.01	0.0002	0.01	0.02	0.01	0.01
Surge Rinse	--	0.0005	0.0001	0.0002	0.005	0.0002	0.0002
Reactor Makeup	0.0032	0.0025	0.0006	0.001	0.0132	0.0571	0.0075
Domestic	--	42	4	5	15	200	1
Raw Well	--	180	8.4	120	45	16.3	3
Fire Protection	--	180	8.4	3946	45	16.3	3
45-Acre Makeup	--	469	1.5	240	10.6	105	40
85-Acre Makeup	--	682	2.8	475	10	99	40
First Stage Clarifiers	--	370	--	160	12	250	58
Second Stage Clarifiers	--	370	--	160	--	185	--
Cooling Water Canal	--	11976	25.1	7905	150	2601	877
Evaporation Ponds	13	98,000	250	42800	80	1200	450
Redhawk Reservoir	0.308	338	--	234.1	5.6	40.22	6.195
Palo Verde Deep Well	--	180	7.8	120	45	13.8	6.4
Redhawk Deep Well	--	325	9.1	300	50	42	27

What is a zero discharge plant ?

- Regulatory requirements in US is very stringent (NRC and EPA). The goal is to eliminate any possibility of public water sources to become contaminated.
- Since Palo Verde NPP is not near or adjacent to any large body of water or natural river, all plant effluent has to be processed to semi dry waste before disposal.
- Palo Verde Nuclear Generating station has "zero" liquid discharge .
- Zero mean below Minimum Level of Detectability , which changes as technology gets better.

Challenges of zero discharge plant

- Integrated water management strategies for overall site is required (Water reclamation and 3 units).
- A large storage and process capacity is a must.
- The segregation of processes is an economical necessity.
- A comprehensive program to control seepage and uncontrolled releases is a regulatory expectation.
- The bottom line is: these additional costs must be recovered by electrical generation.

Tower technology selection is critical to long-term performance station

1. Cooling towers consumption could limit the maximum power and technology selection of NPP.
2. Processing cost of effluent from the Tertiary is significant.
3. Cost / power consumption of pumpage , Waste Water Treatment Plant, maintenance and replacement of pipe-line should be included in the selection the technologies for cooling tower.
4. Meteorological conditions (future and past) make a significant impact on sizing of the components and systems.

Tradeoff	Cooling System Type				
	Once-Through	Wet Mechanical Draft	Dry Air-Cooled Condenser	Hybrid Wet/Dry	
				Plume Abatement	Water Conservation
Water Consumption	Minor	8 to 12 gpm/MWe	~ 0 to <5% of wet tower	~ equal to wet tower	20% to 80% of wet tower depending on design
Capital Cost	<< **BASE**	**BASE**	1.5x to 3x base	1.1x to 1.5x base	3x to 5x base
O&M Cost	< **BASE** Pump maintenance, condenser cooling	Highly site specific; fan/pump power; water treatment; tower fill/ condensate cleaning	Finned surface cleaning; gearbox maintenance; fan power	Similar to **BASE**	Similar to **BASE**
Performance Penalty	< **BASE** Base penalty depends on site meteorology	**BASE**	Highly site specific—5% to 20% capacity shortfall on hot and windy days	~ Equal to base	Highly variable, depending on mode of operations
Water Withdrawal	~500gpm/MWe	10 to 15 gpm/MWe	None	~ Equal to base	Variable, but can be reduced from wet by amount of water conservation
Discharge	~500 gpm/MWe; thermal plume and residual chlorine issues	2 to 5 gpm/MWe	None	~ Equal to base	Variable, as with withdrawal
Drift	NA	Negligible;< 0.001% of circulating water flow	None	Small reduction from wet	Similar to wet when used in wet mode
Plume	NA	Visible plume on cold, humid days	None	None	None during normal operating schedules

Operational challenges

- Long term negotiation of water rights and obtaining a contract with Phoenix metropolitan.
  - Interest in reclaim water is increasing
    - Resorts and gulf courses.
    - Cities and recreation lakes .
    - Environmental conservationists.
- Water Reclamation Facility changes
  - Storage - additional pond was built to maintain reliability and capacity of power units .
  - Underground piping deterioration and need for redundancy
  - Radioactivity in influent from city due to medical treatments
    - Considerable issue for zero discharge site , is the iodine power plant generated?
  - Landfill and disposal .

Operational challenges

- Erosion / Corrosion issues with plant underground water delivery systems
  - Cooling towers and piping material section.
  - Cathodic protection – galvanic reaction.
  - Corrosive soil and water, chlorides and sulfates.
- Need for additional storage capacity
  - Power uprates (CST , UHS)
  - Additional plant testing requirements.
  - Dry storage cask manipulation.
- Seepage control and H-3 issue
  - Structures are not 100% water tight .
  - Leakage is inevitable .

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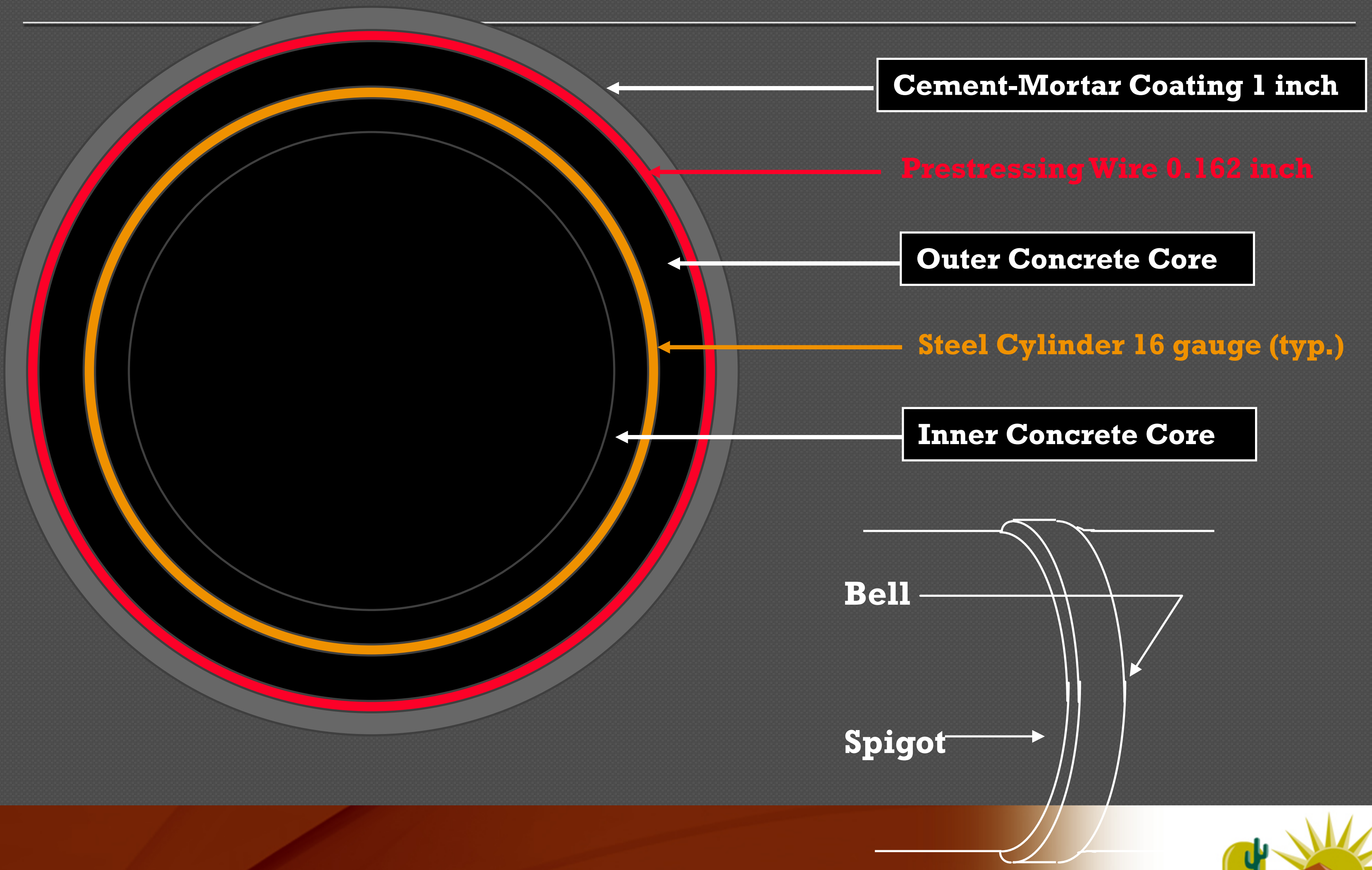
Underground Pipe – external through wall pit

Aboveground Pipe

WRSS PIPELINE RECOVERY

WRSS Pipe Section Profile



Repairs

Spray pond leaks at monolith joints

Cooling towers degradation

Causes and solutions

- **Causes**
  - Water chemistry (sulfate and Chlorides).
  - Susceptibility of pre-tensioned concrete members rebar (standard) corrosion.
  - Failure to provide minimum rebar protection.
  - Poor selection anchor – bolts material (hard ware) and proper cathodic protection .
  - Poor Quality assurance.
- **Solutions**
  - Change design of members to non pre-tensioned-concrete with coated rebar. Reason based fiberglass was rule out due to desert environment)
  - Assure proper rebar coverage
  - Use of stainless steel bolts and hard ware (Grade 904 L) when possible The bolts are place using epoxy.
  - Increased quality assurance (construction, assembly and maintain ace).
  - Cathodic protection.

Cooling tower after completion of repairs

Operational challenges for the station

- Effluent from the units exceeds the design expectation.
  - The method evaporation is more complex than simple use of meteorological averages .
  - The capacity of evaporation ponds had to be increased by 3 folds.
  - The pond maintenance and design is a challenge.
  - Monitoring the pond for release has been a challenge.
  - Even at below detectable radioactive limits ponds become radioactive during the life of the station which requires radiological control.
  - Dust accumulation is also a factor.
  - Control migratory birds, fish and flora and fauna are yet another challenge.

Key changes to SBO as a result of the Fukushima event

US Regulatory and industry organizations are focused on extending the station black out (SBO) rule (50.63). In summary

- Extending scope of the SBO event (all loss of AC) from site specific duration to minimum of 24 or possibly 72 hr.
- All sources of water to cool primary or provide make up to primary needs to be ***DESIGNED*** to mitigated external events (seismic , tornado, flooding ..) .
- Non- design basis water storage and retention structures shall not cause flooding as a result of any external event.
- No external personal and organization should be relied upon within the first 24 hours.

Future challenges

- The water infrastructure at Palo Verde NPP is non-quality and not designed for external events– Significant work has to be performed to assess fragility of these structures and systems.
- New maintenance, testing procedures will be required.
- Human Resources to implement strategies are significant and they have to be identified and available at the site 24/7.

Palo Verde Nuclear Generating Stations 2012

Hamid.Mortazavi@aps.com

Or WANO