Design of piped water supply (PWS) schemes

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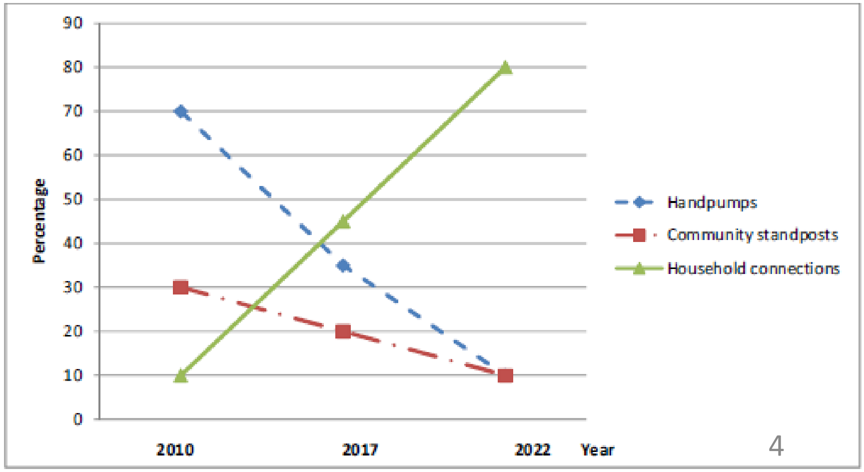
Agenda

- Introduction to Piped water schemes (PWS)
- Design of PWS
  - Define demand
  - Service level consideration
  - Source identification
  - ESR location and capacity design
  - Pipe layouts
  - ESR staging height and Pipe diameter
  - Pump design
  - Cost optimization

Water sources for different uses

Relevance of PWS

- The need for PWS
  - Falling ground water levels
  - drudgery removal, aspiration for many rural households, improved water quality in case of WTP
- GoI strategic goal to have 90% of all households with PWS by 2022
  - Currently at about 30%



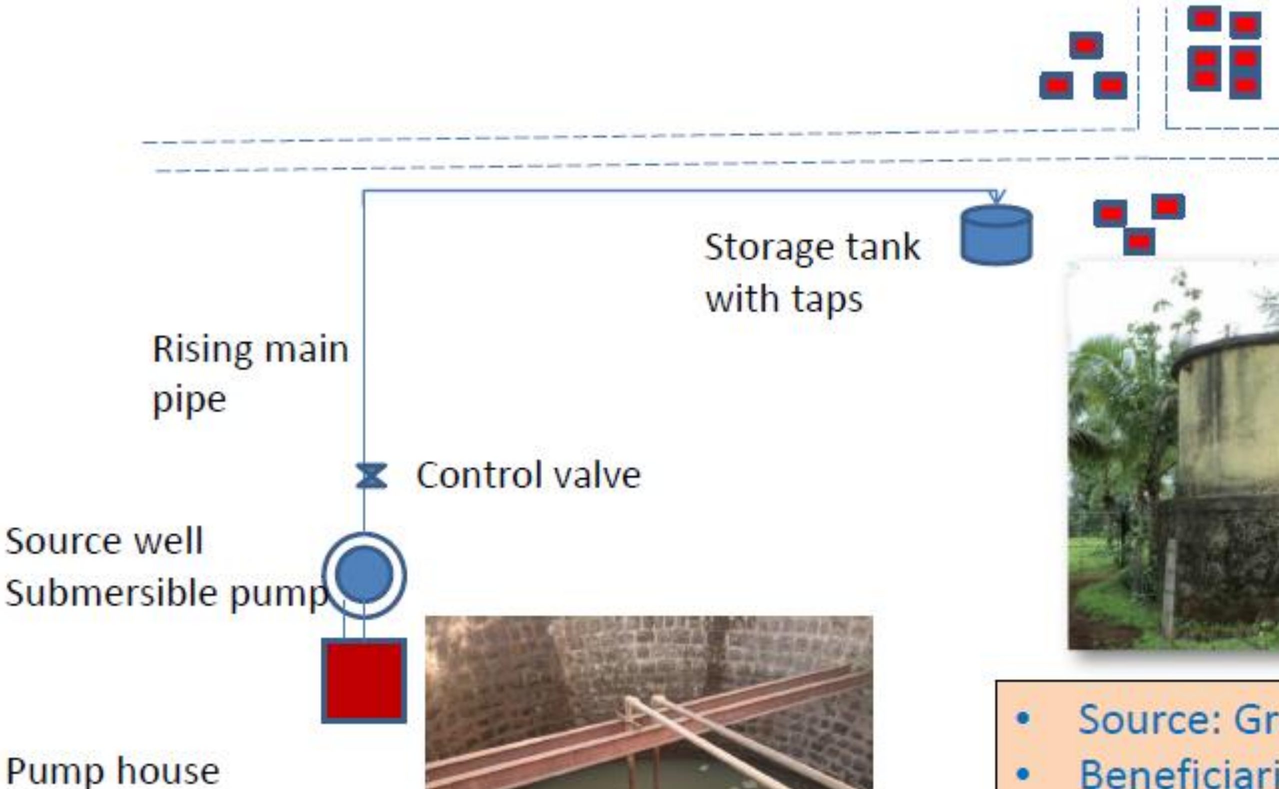
Source: NRDWP Strategic Plan 2011-2022, GoI

PWS Components

- Source
  - Groundwater, surface water
- Transmission
  - Network of pipes, tanks
- Delivery
  - Public stand-posts, household taps

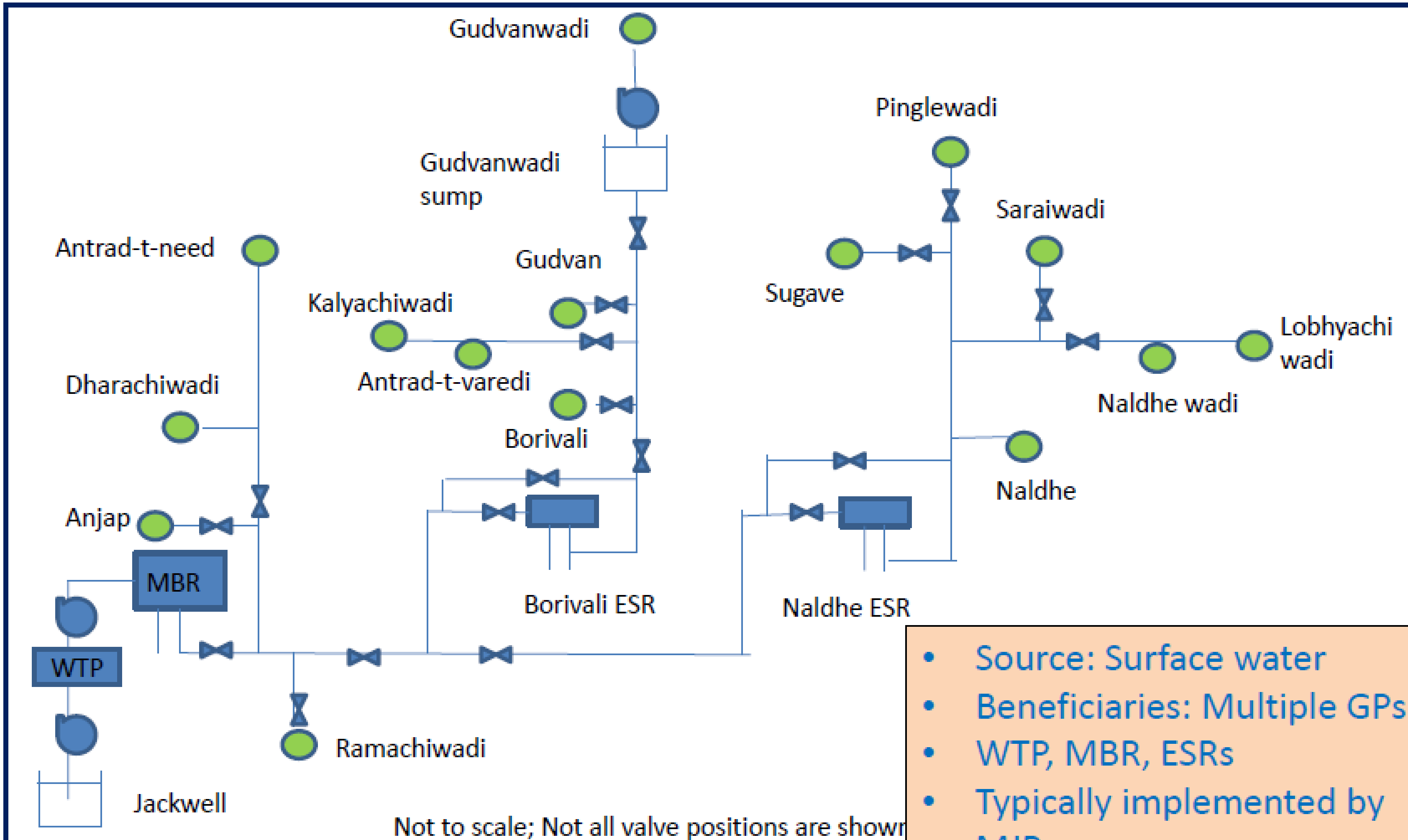



Typical Single Village PWSS



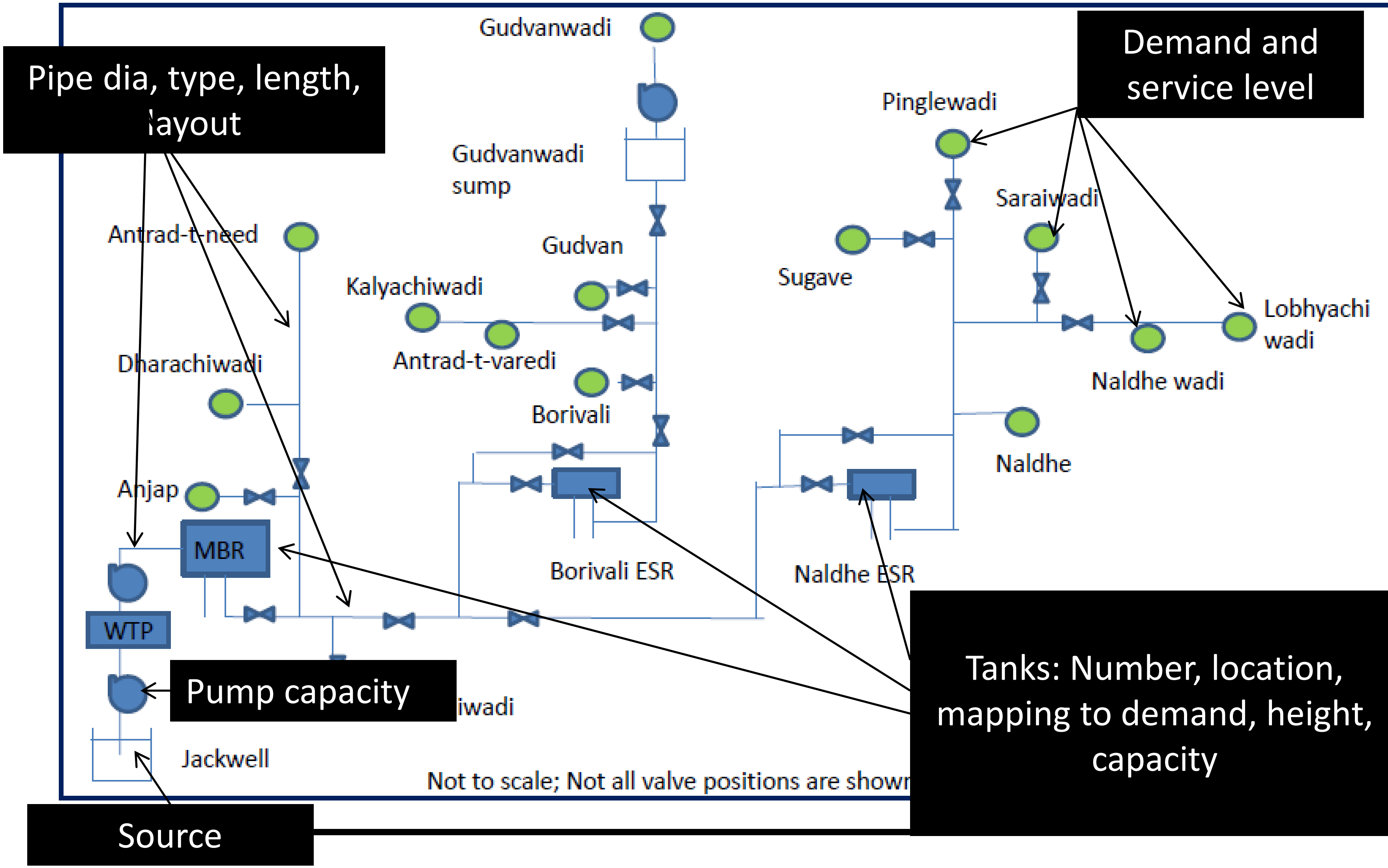
- Source: Groundwater
- Beneficiaries: One or more habitations within a GP
- One or more storage tanks
- Typically implemented by MI, RDW or private TSP

Multi village scheme (MVS) or Rural Regional scheme (RR)



- Source: Surface water
- Beneficiaries: Multiple GPs
- WTP, MBR, ESRs
- Typically implemented by MJP

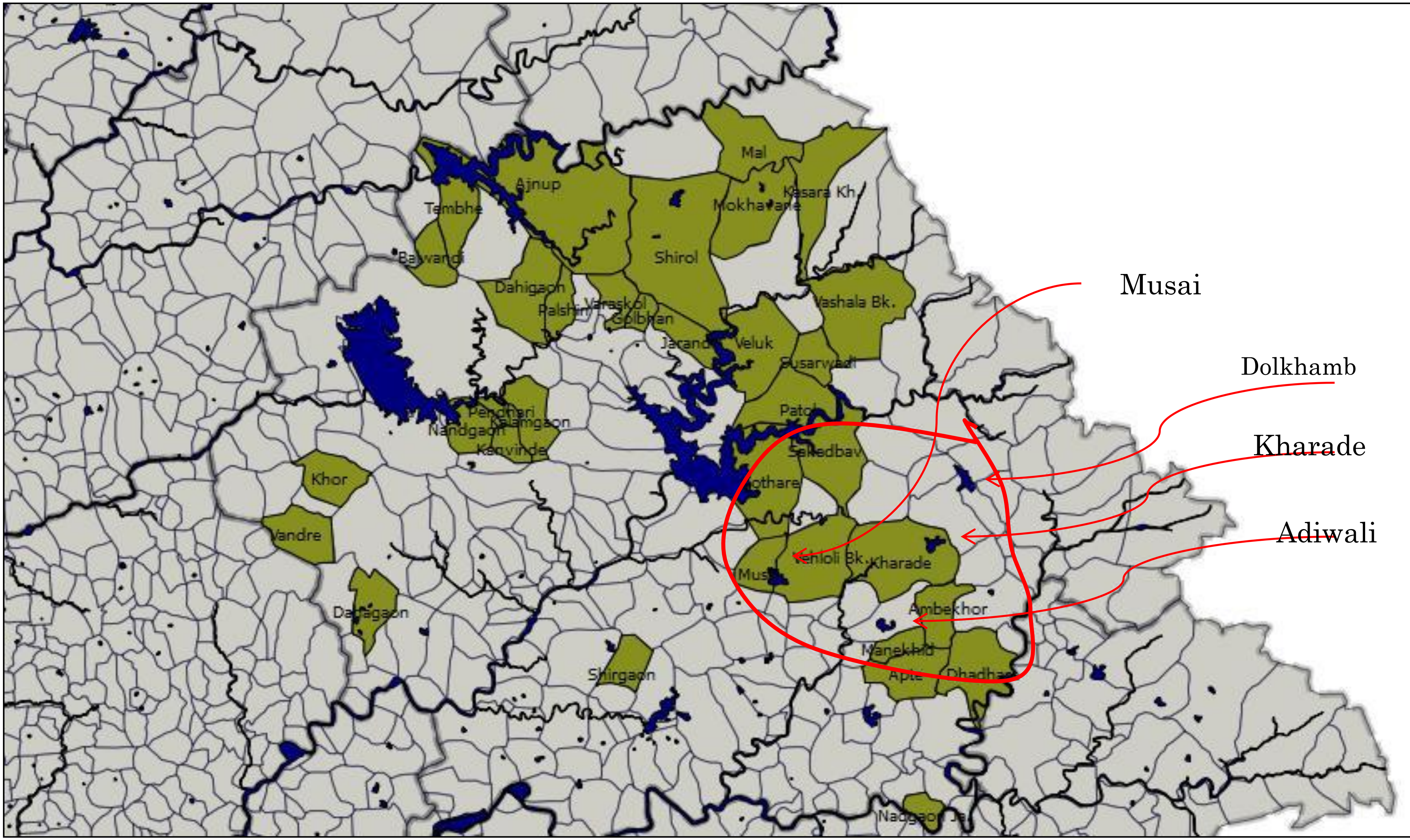
Designing a PWS – what does it entail?



Design of a PWS scheme

- Characterize demand
  - Identify habitations
  - Population
    - account for growth (ultimate stage population)
    - account for cattle population
  - LPCD norm for design (40/ 55/ 70/130 etc.)
- This gives us requirement for average daily demand from the source
  - ultimate stage population * lpcd

Identify source options

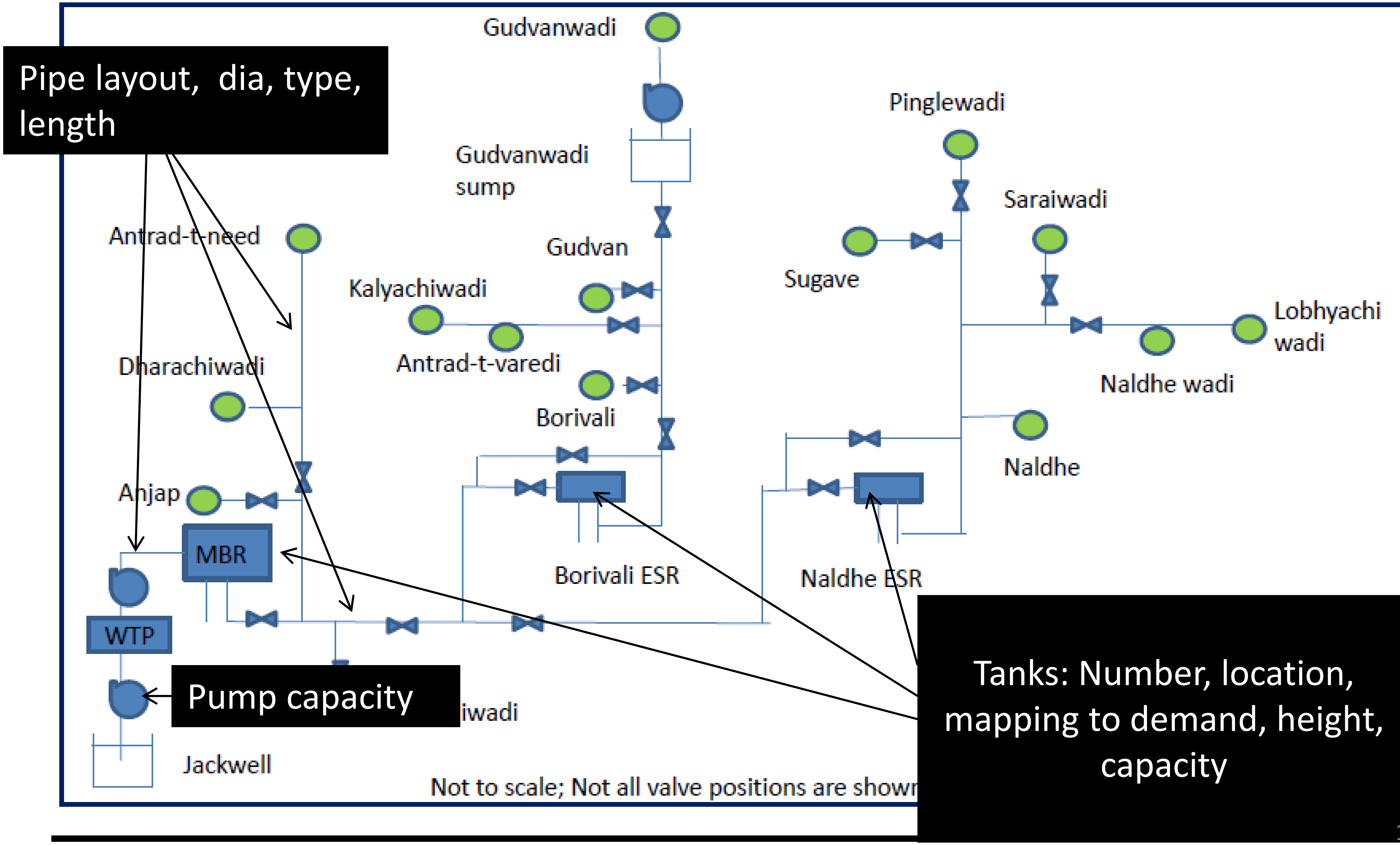


Source: Analysis of tanker fed villages in Shahpur by Divyam Beniwal, Pallav Ranjan

Considerations for source identification

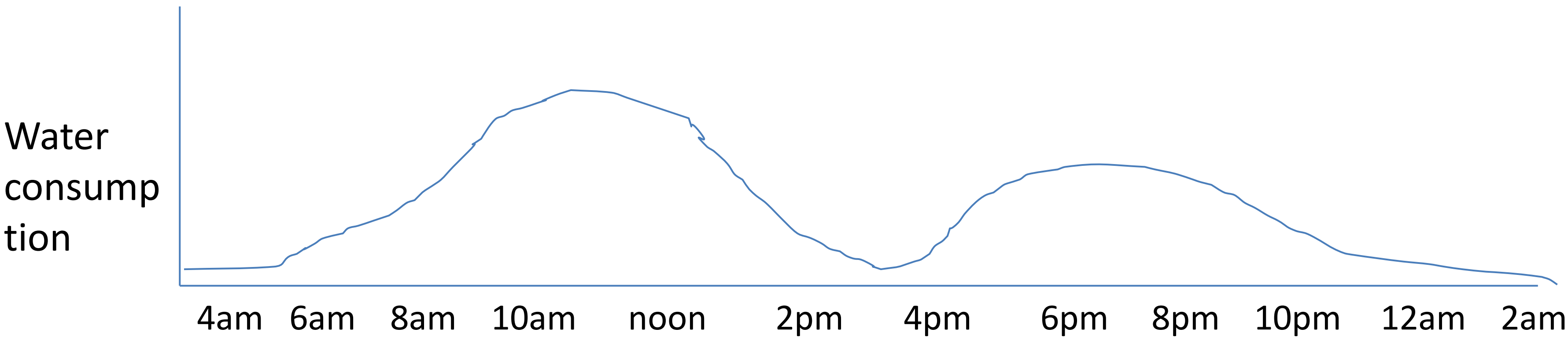
- Yield
  - Will it meet the demand?
    - Surface source: reservation for drinking water
    - Ground water: Perform an yield test
- Water quality
  - WTP required for a surface source
- Distance from target habitations
  - Long distance => long pipelines => high investment cost
  - high frictional losses & high leakages => hence, high recurring operational cost
- Elevation difference between source & target
  - Big difference => high pumping cost (recurring)
  - If source is at higher elevation => low operational cost

Design of transmission network – expected output

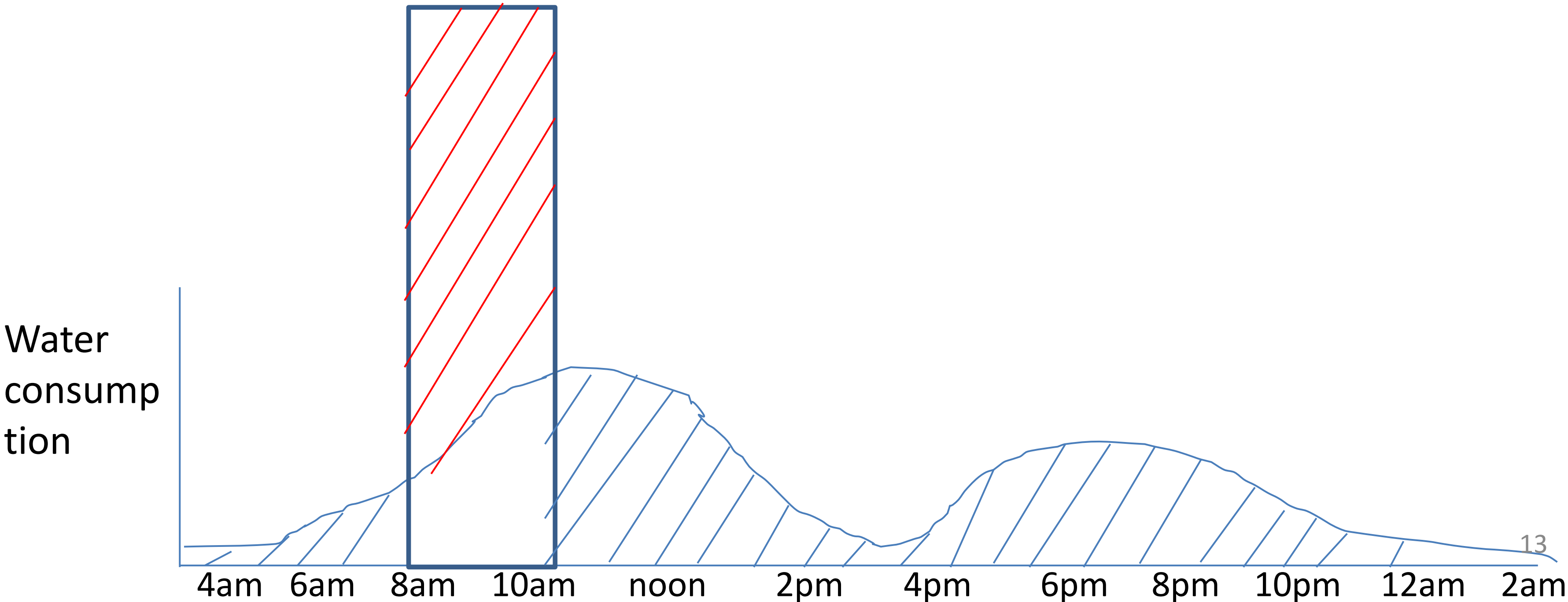


Design parameters depend on demand pattern

- 24x7 water service



- Intermittent service



How does service level impact asset design

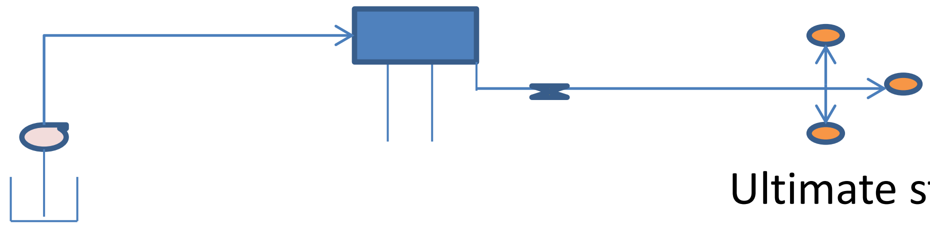
- Total daily demand supplied in 2 hours => 12x increase in average outlet flowrate
  - How does this impact
    - Pipe diameter?
    - ESR storage capacity?
    - Pump capacity?
  - In general, 24x7 service => lower asset cost compared to intermittent service

Flowrates

- Demand flow rate
  - Variable for 24x7 supply: depends on consumption
  - Intermittent supply: depends on designed service hours
- Supply flow rate
  - Amount of water to be pumped (demand + x% leakages etc.)
  - Pumping hours
    - Depends on electricity outages

ESRs help in meeting the demand flow rate while maintaining supply at a constant average flow rate

Example

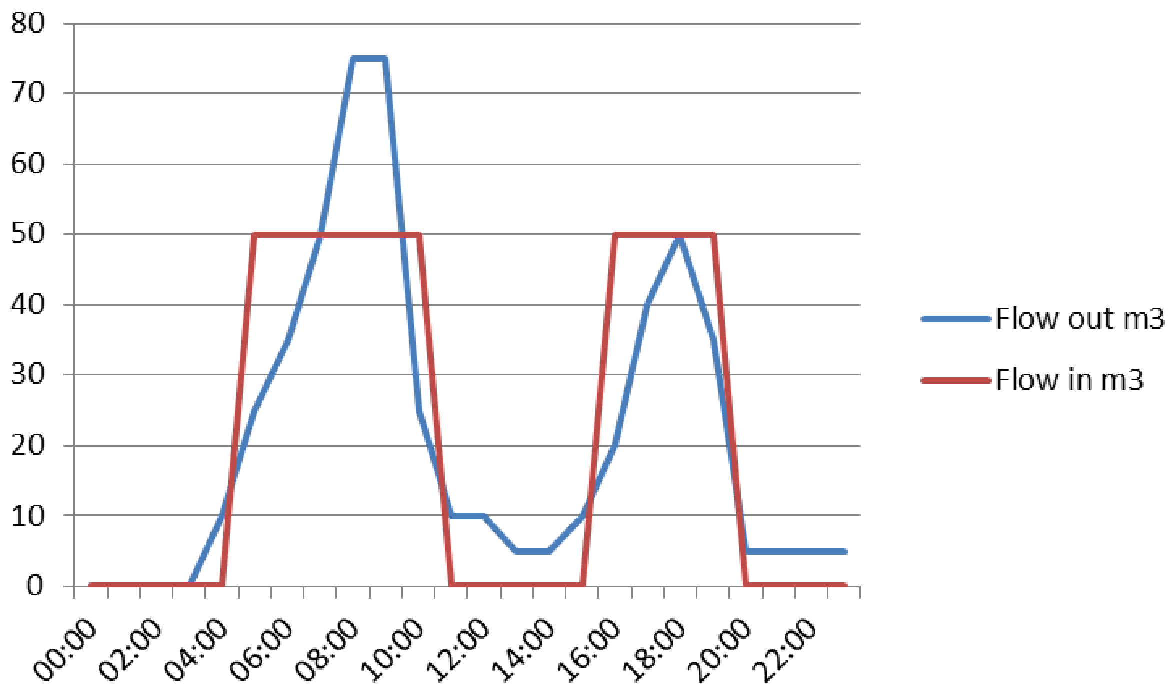


Ultimate stage
population = 10,000

- Demand = 10,000*50 lpcd = 50 m^3 per day
- Service Hours
  - 24 hours service : Average demand flowrate = 50/24 m^3/hr = **2.08** m^3 **/hr**
    - Caution: this is **average** flow taken over service hours
- Pumping hours: Assume 10 hours
  - Supply flow rate = 50 m^3 /10 hr= 5m^3/hr in 10 hours

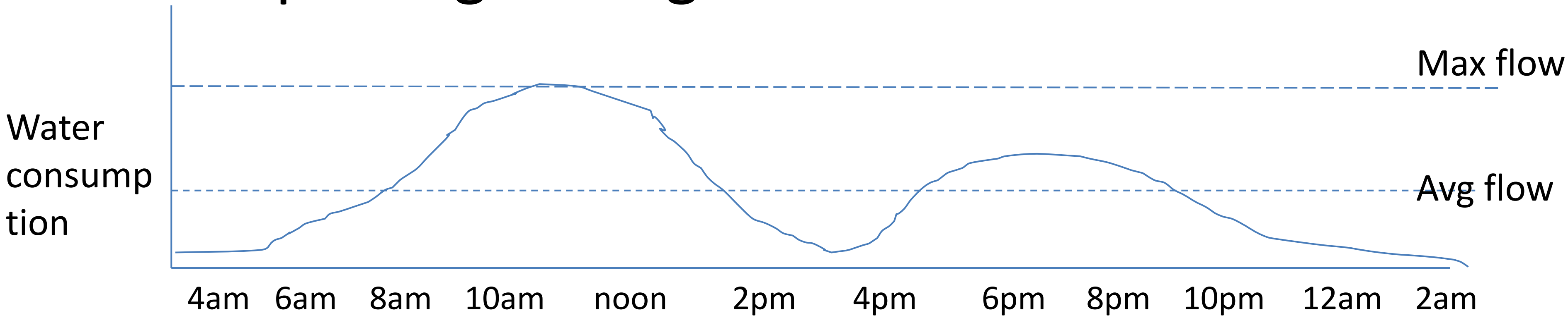
Example contd.

- Consumption is usually variable
  - 24 hour service (variable demand)
  - 10 hours of pumping (supply)



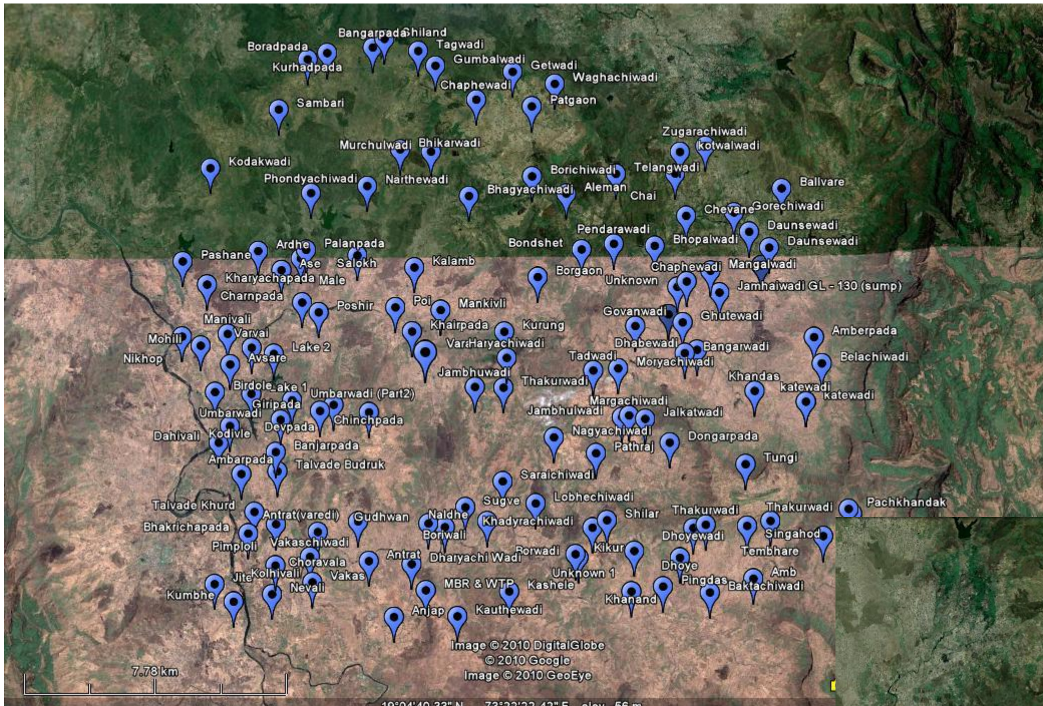
Benefits of ESRs

- Pump sizing for avg flow vs. max flow

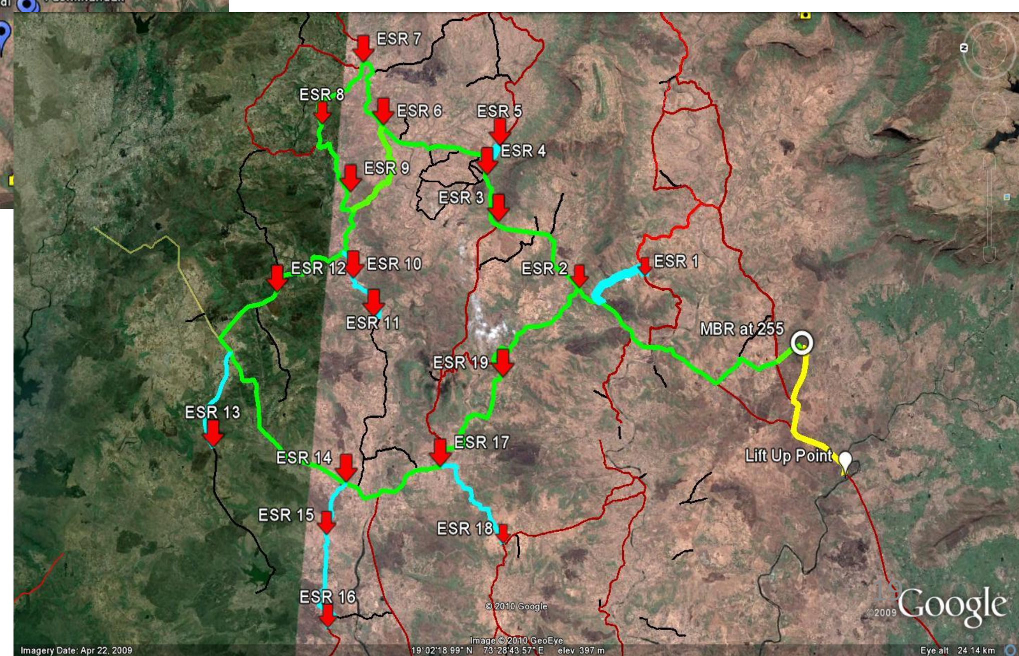


- Buffer capacity
  - Peak consumption times
  - Electricity outage
- Providing hydrostatic "head"

Location and count of ESRs



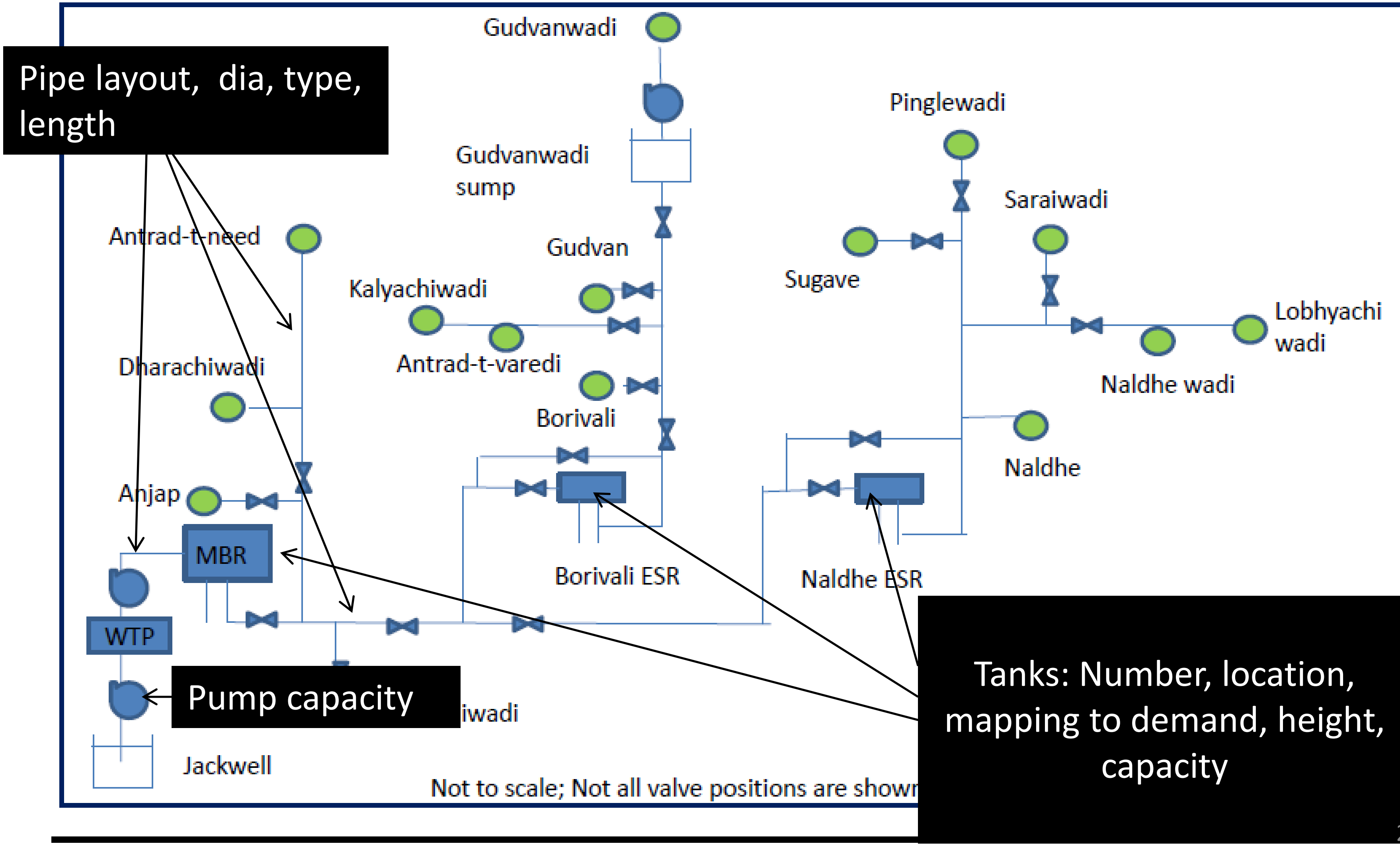
- Cluster based on
  - Distance
  - Elevation
  - Population
- Practical considerations – land availability



- Physical inspection required for accurate elevation data

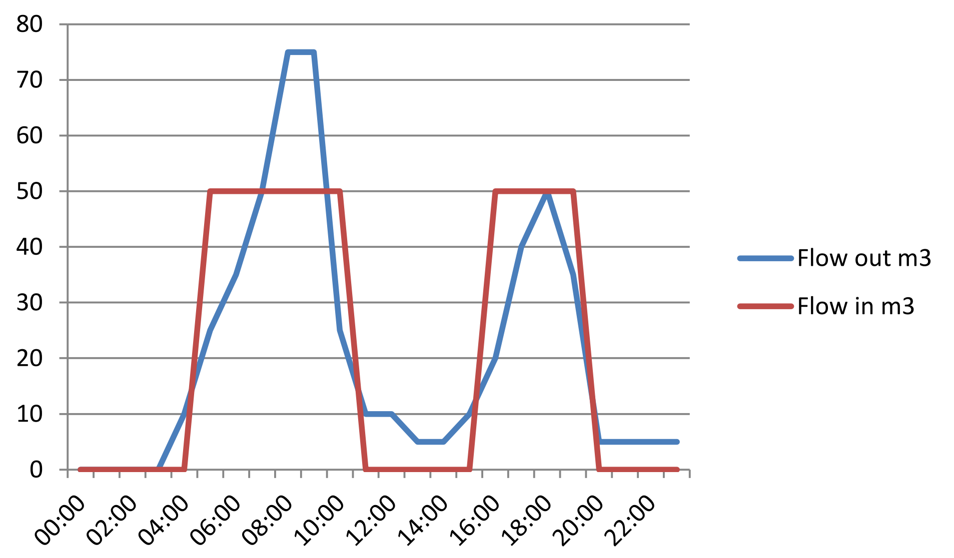
Source: North Karjat Feasibility Study by Vikram Vijay and team

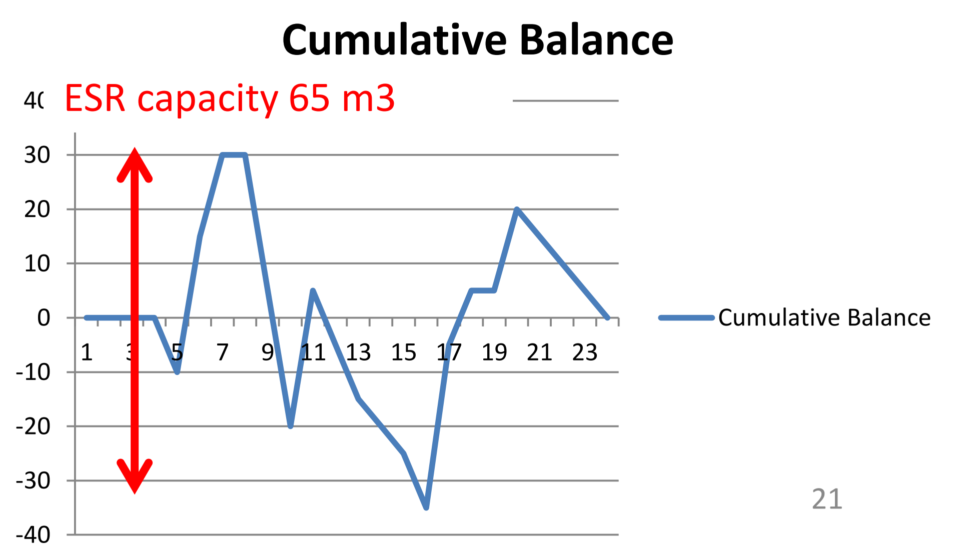
Design of transmission network – expected output



ESR Capacity Sizing – Back to the Example

Hour	Demand %	Flow out m3	Flow in m3	Balance	Cumulative Balance
00:00	0%	0	0	0	0
01:00	0%	0	0	0	0
02:00	0%	0	0	0	0
03:00	0%	0	0	0	0
04:00	2%	10	0	-10	-10
05:00	5%	25	50	25	15
06:00	7%	35	50	15	30
07:00	10%	50	50	0	30
08:00	15%	75	50	-25	5
09:00	15%	75	50	-25	-20
10:00	5%	25	50	25	5
11:00	2%	10	0	-10	-5
12:00	2%	10	0	-10	-15
13:00	1%	5	0	-5	-20
14:00	1%	5	0	-5	-25
15:00	2%	10	0	-10	-35
16:00	4%	20	50	30	-5
17:00	8%	40	50	10	5
18:00	10%	50	50	0	5
19:00	7%	35	50	15	20
20:00	1%	5	0	-5	15
21:00	1%	5	0	-5	10
22:00	1%	5	0	-5	5
23:00	1%	5	0	-5	0
		500	500		

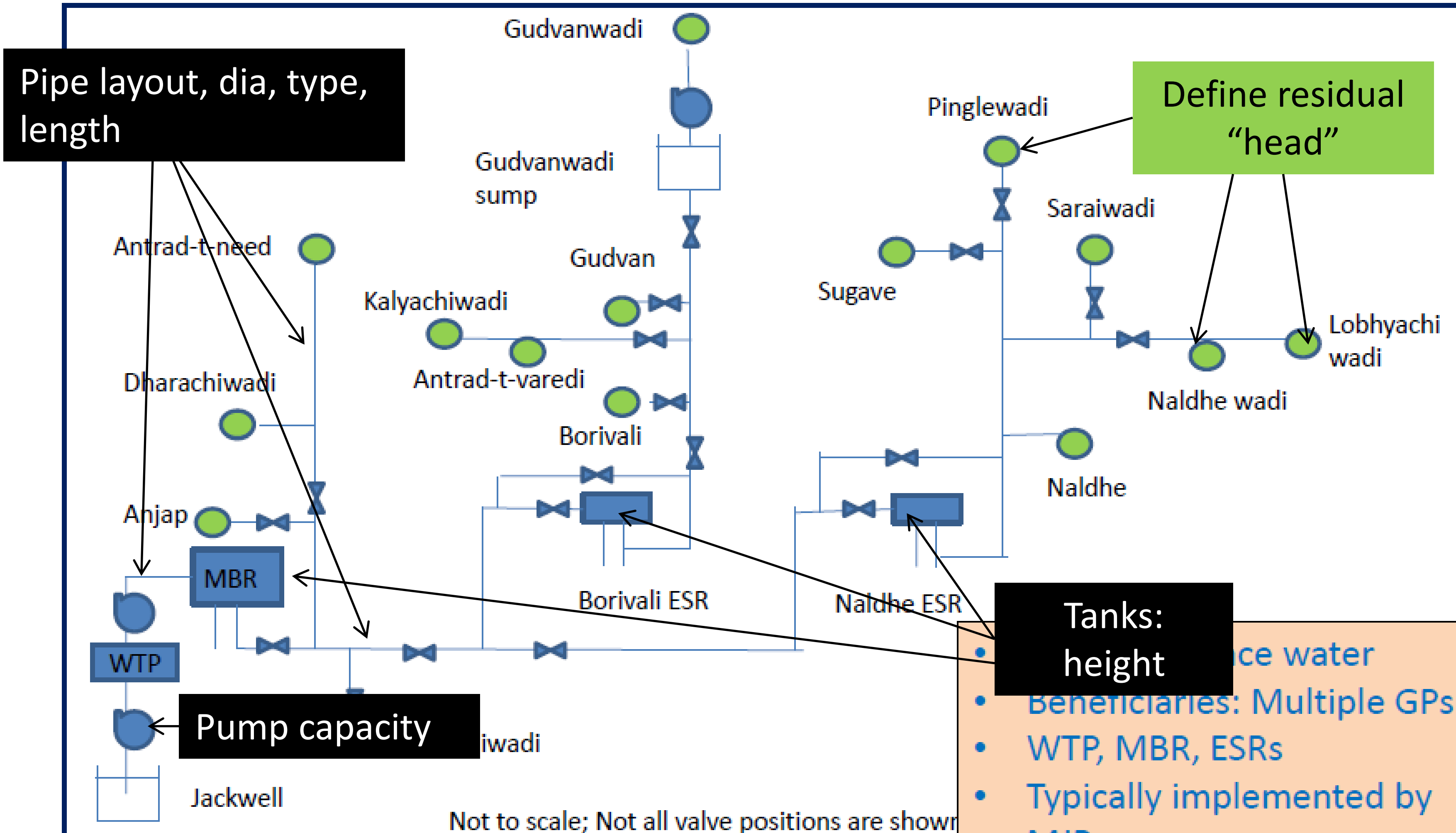




Why MBR?

- MBR – Master Balancing Reservoir
- Feeds the ESRs
- Holds additional x hours of buffer capacity
- Balances fluctuations in demand from ESRs against supply

Design of transmission network

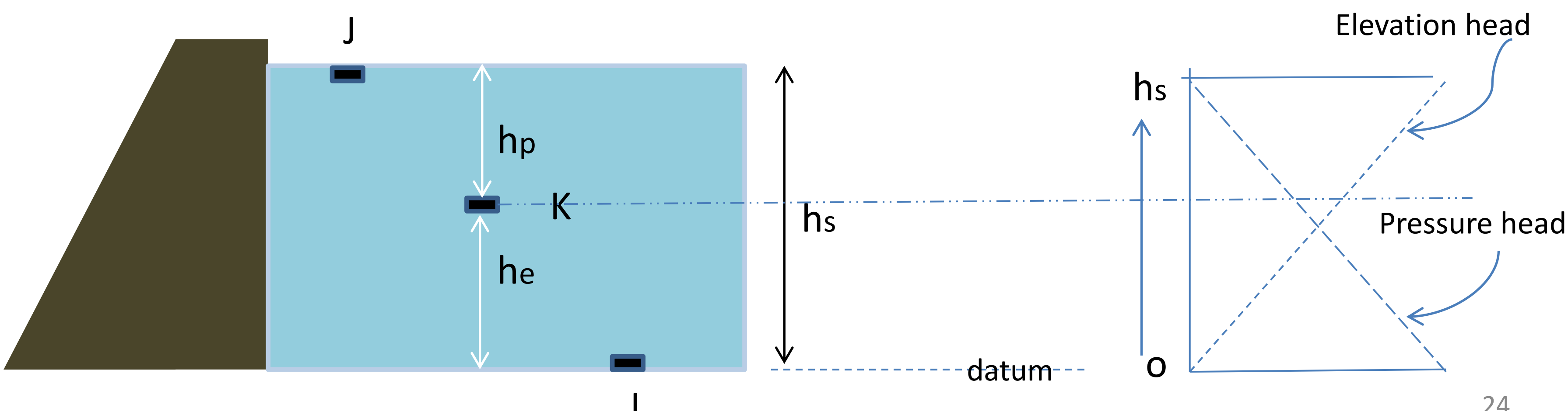


- ce water
- Beneficiaries: Multiple GPs
- WTP, MBR, ESRs
- Typically implemented by MJP

What is head?

- Hydraulic head: Total energy in a fluid
  - Elevation head, pressure head, velocity head
- By Bernoulli's principle: Hydraulic head = elevation head+ pressure head + velocity head is constant

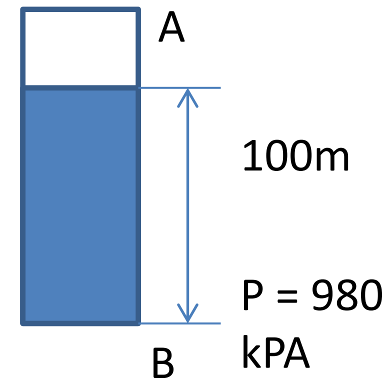
- Pressure head at A = elevation head at B = ρgh



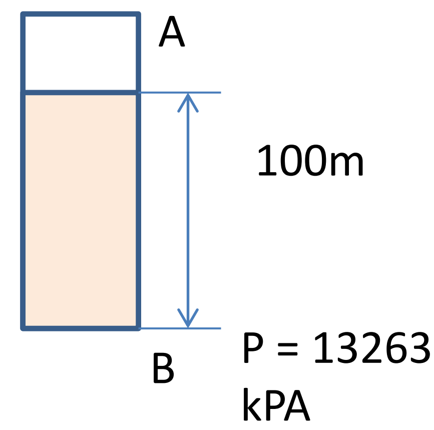
Source: examples from Introducing Groundwater by Michael Price

Use of “head” in specifications

- Assume a column of water
  - Pressure head at B = 100m
  - Pressure at B = ρ* g* h = 1000 kg/m3*9.8 m/s2 * 100m = 980kPa



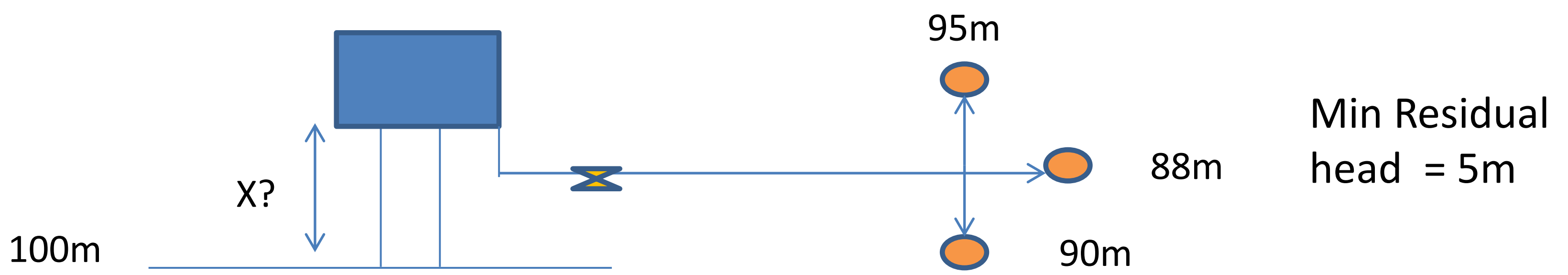
- Pressure depends on density of fluid
  - Pressure at B for a column of mercury = 13534 kg/m3 *9.8 *100 = 13263 kPa



- Easier to specify required head or discharge head instead of pressure -> no longer dependent on the fluid density

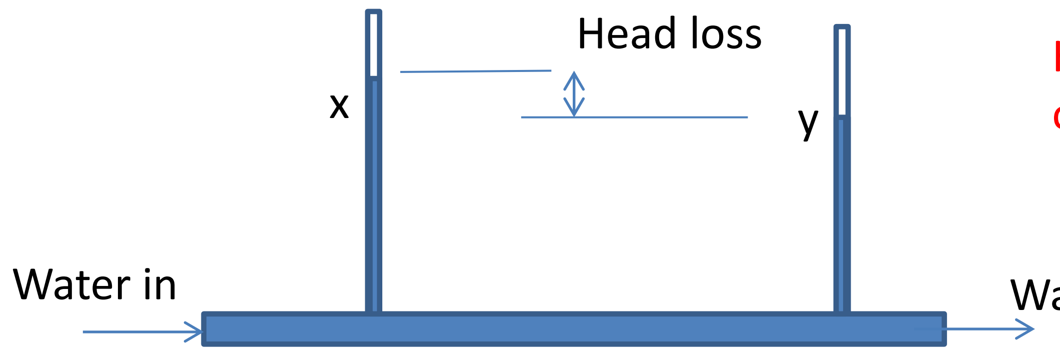
Design ESR staging height

- Define minimum residual head at delivery points



- Minimum required staging height depends on
  - Elevation of supply / demand points
  - Minimum residual head requirement
  - and something else?

Frictional losses

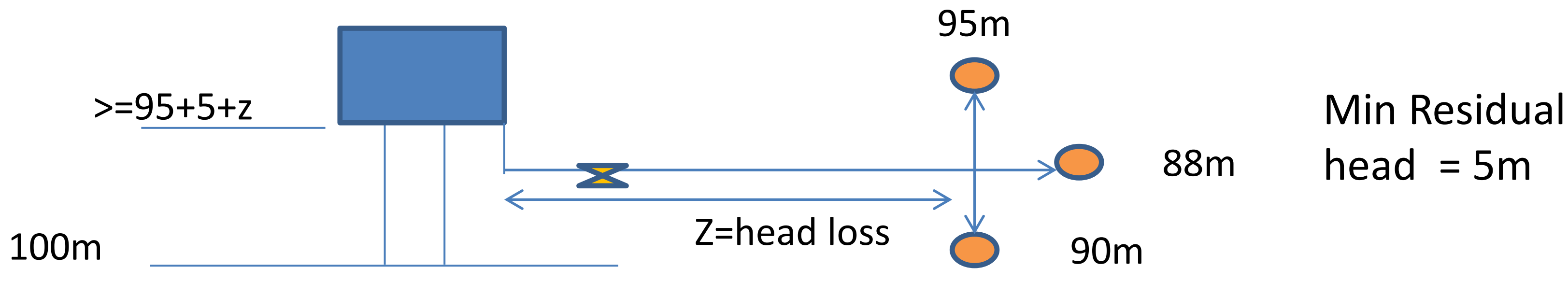


How does conservation of energy hold here?

- Total head loss (m of head loss/ km distance per m/s velocity)
  - Pipe roughness
  - Pipe length
  - Flow rate
  - Pipe diameter
- Pipe Roughness constant:
  - Published for different materials
  - Many models and empirical equations in literature to calculate head loss using this constant

Source: example from Introducing Groundwater by Michael Price

Design ESR height

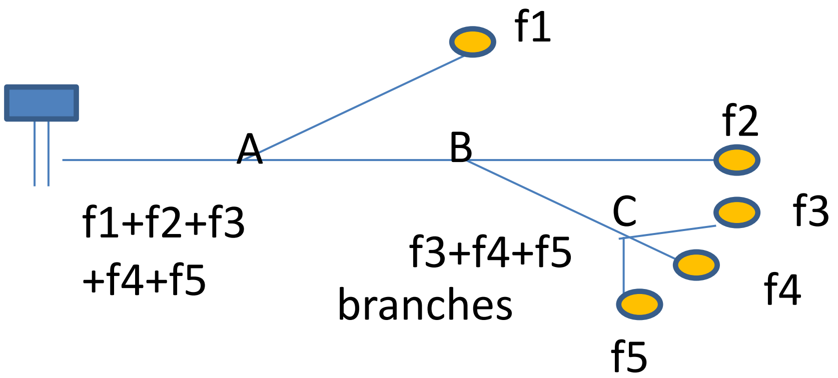


- When can we use a GSR?
- Trade-off between pipe dia and tank staging height
  - High staging height => low pipe diameter needed to achieve the same head why?
  - Also implies higher pumping cost (Upstream impact – recurring cost)

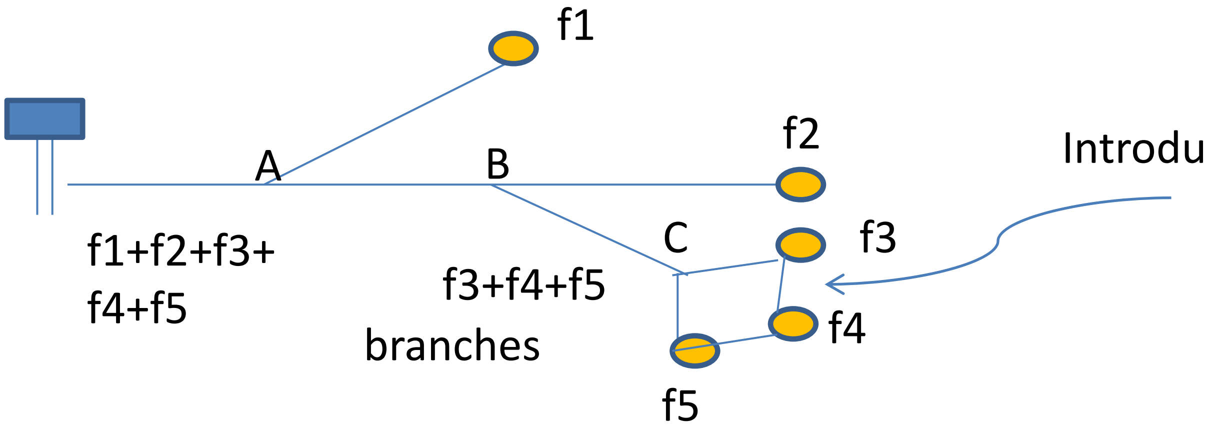
Pipe Types

- Pipe type usually driven by cost
- Most used types: PVC, GI (Galvanized Iron), HDPE (High density polyethylene), MDPE
  - PVC: Most commonly used; low cost, easily installed. Prone to leakages, requires frequent maintenance
  - GI: good for pipes installed over ground and can be easily welded but more expensive and prone to corrosion
  - HDPE/MDPE: cheap, inert, comes in rolls of hundreds of meter, very low leakage. Electrofusion of joints requires expensive equipment; lower availability

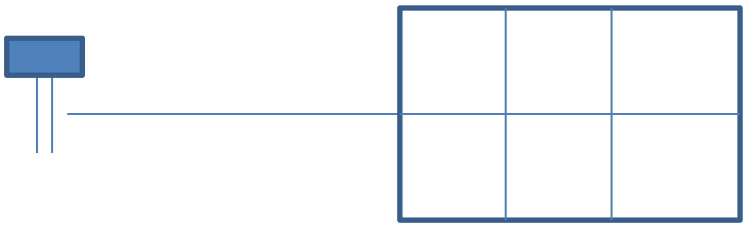
Pipe Layout



Branch network



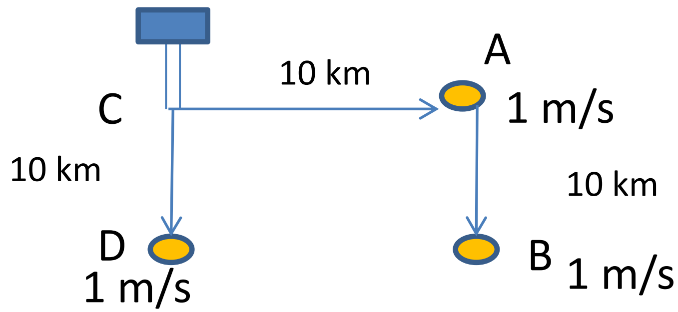
Introducing a loop



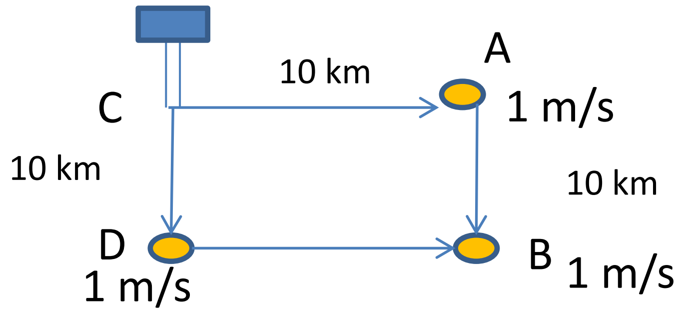
Grid network

Example - Loops

Frictional loss = 1m/ km per m/s velocity



Branch	velocity	loss
A-B	1m/s	10m
C-A	2m/s	20m
C-D	1m/s	10m



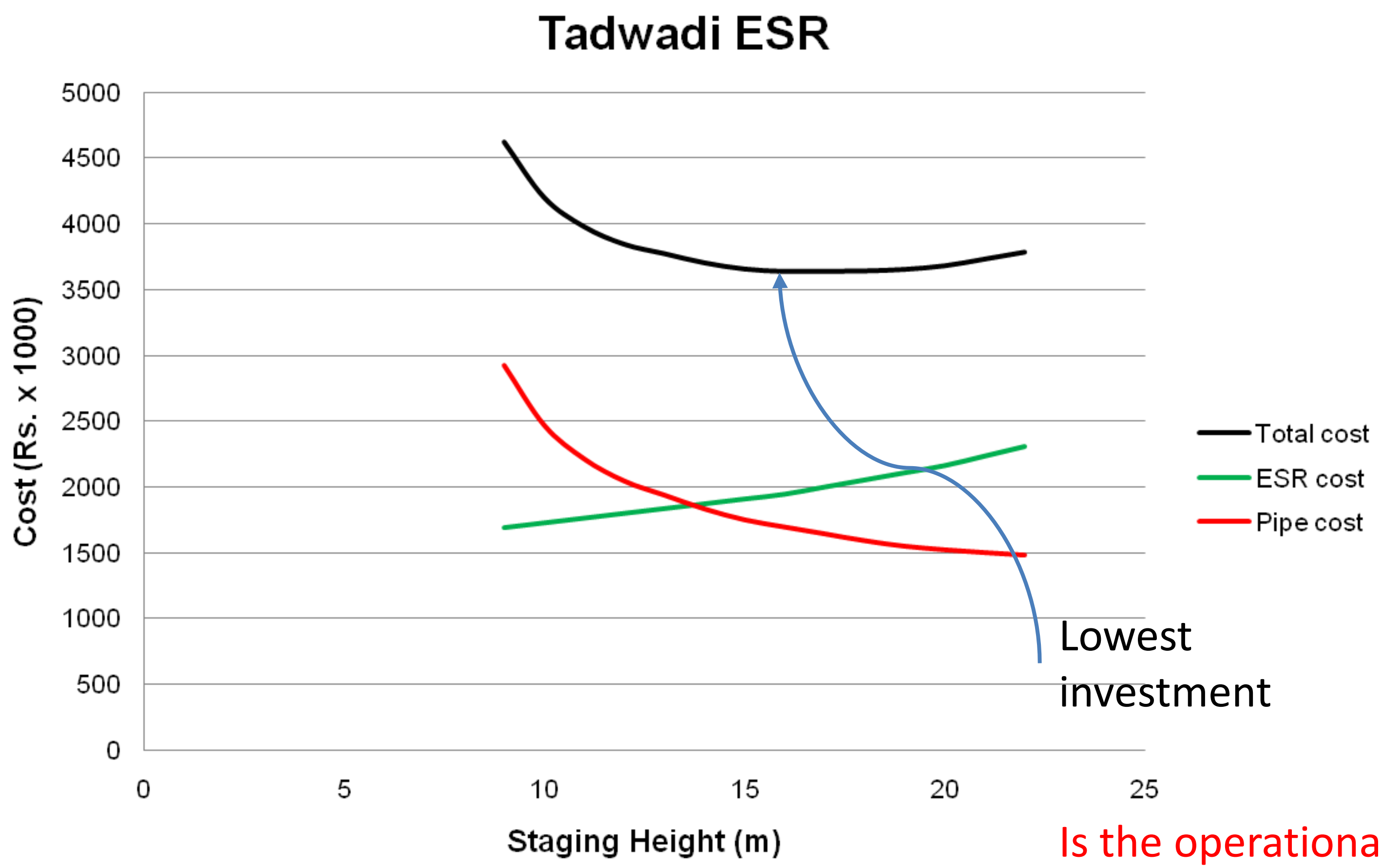
Branch	velocity	loss
A-B	0.5 m/s	5m
C-A	1.5m/s	15m
D-B	0.5m/s	5m
C-D	1.5m/s	15m

Introducing the loop reduced the ESR height requirement

Back to ESR height vs. pipe design

- Start with any reasonable ESR height
- List available options of {pipe dia, friction coeff, cost}
- For the given network and available pipe choices determine the optimal pipe choice for each branch such that the total pipe cost is minimized
- Optimization software such as Branch/Loop may be used for this

Back to ESR height vs. pipe design



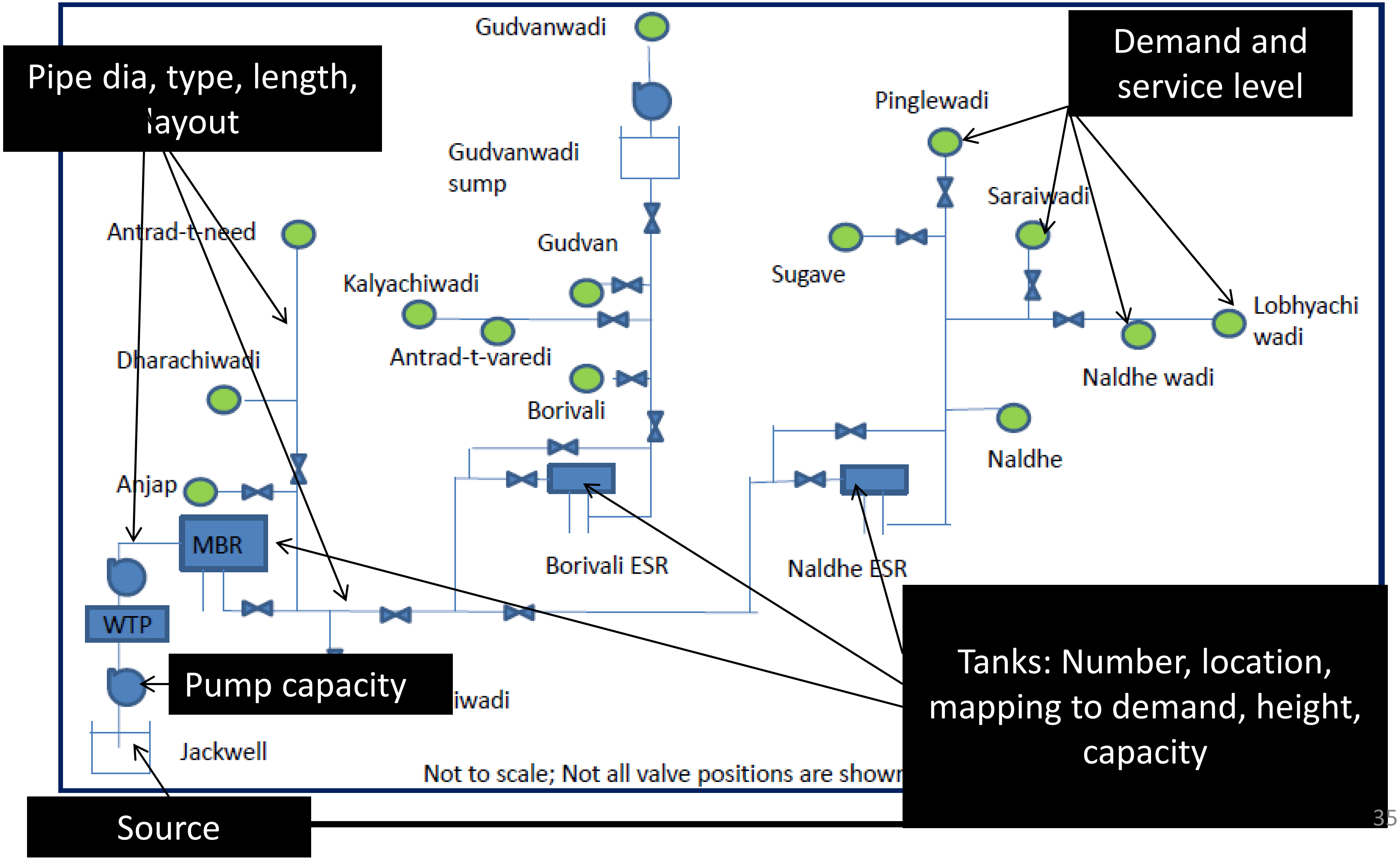
Is the operational cost acceptable?

Pump specs

- Pump power is proportional to
  - $Q*\rho*g*h$
  - Q supply flow rate
  - h differential head between pump and MBR

    (static head + frictional head + velocity head)
  - ρ fluid density;

Review



Gudvanwadi
Gudvanwadi sump
Gudvan
Kalyachiwadi
Antrad-t-vared
Antrad-t-varedi
Dharachiwadi
Borivali
Anjap
MBR
WTP
Borivali ESR
Jackwell
iwadi
Pinglewadi
Saraiwadi
Sugave
Lobhyachi wadi
Naldhe wadi
Naldhe
Naldhe ESR
Pipe dia, type, length, layout
Demand and service level
Pump capacity
Source
Tanks: Number, location, mapping to demand, height, capacity
Not to scale; Not all valve positions are shown

Some useful references

- Mokhada MVS design report: http://www.cse.iitb.ac.in/~sohoni/water/MokhadaMVS.pdf
- Khardi scheme proposal using Kundan dam: email me for a copy
- North Karjat RR scheme feasibility study: http://www.cse.iitb.ac.in/~sohoni/karjatshort.pdf
- Sugave MVS scheme analysis: http://www.cse.iitb.ac.in/~sohoni/mvs.pdf
- Tadwadi SVS scheme failure analysis http://www.cse.iitb.ac.in/~sohoni/svs.pdf