Best Practices in Installation of Solar Water Pumping Systems

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5. Installation of solar water pumping systems
    - Installation of PV array
    - Cabling and Interconnections
    - Installation of motor-pump unit

Type of solar water pumps and different Components

Type of solar water pumps

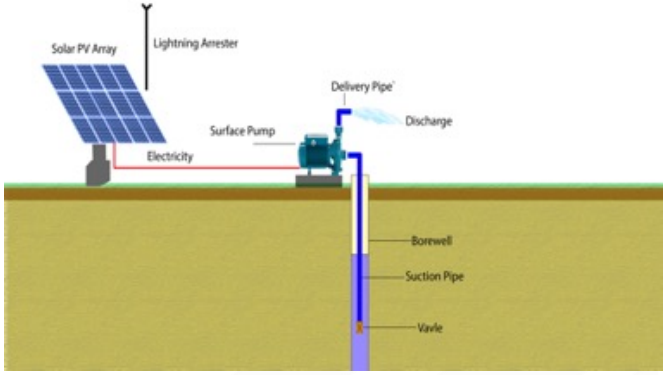
Surface Pumps

There are namely two general types of pumps used in solar water pumping applications - centrifugal and positive displacement. Both centrifugal and positive displacement pumps can be further classified as:

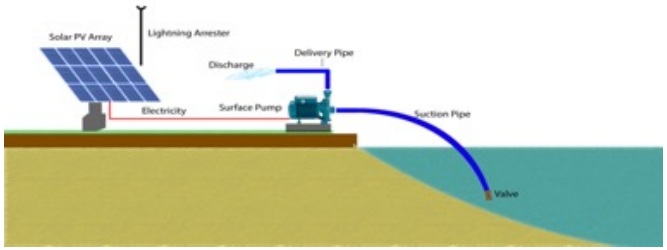
(1) Surface Pumps (motor mounted on the surface)

(2) Submersible Pumps (motor placed into the water)

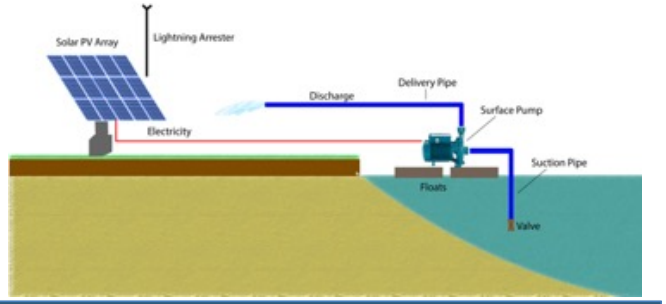
Surface pump to lift water from a shallow tube well or bore well



Surface pump to lift water from a surface water source



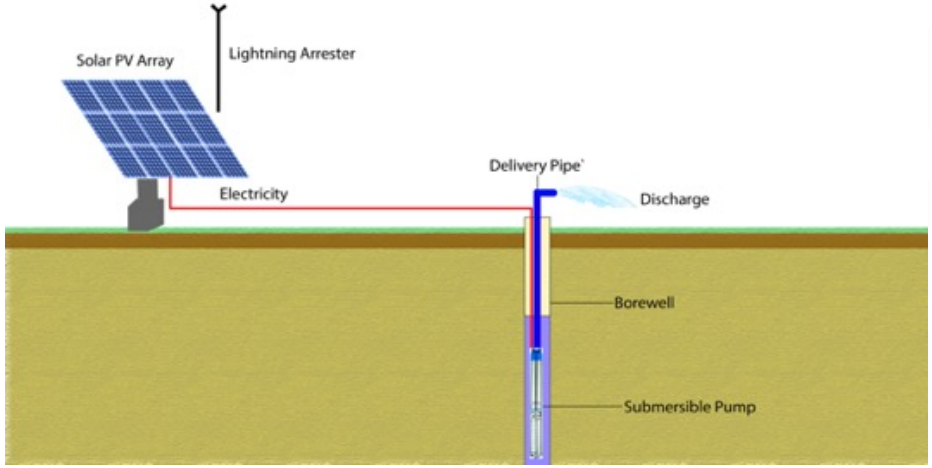
Surface pump installed on a float to lift water from a surface water source



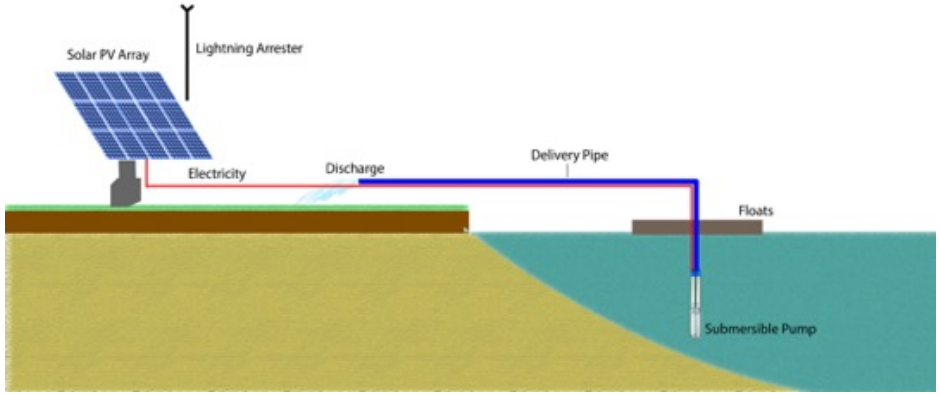
Type of solar water pumps

Submersible Pumps

In a centrifugal submersible water pump, the DC or AC motor is kept in a waterproof enclosure which is directly connected to the pump. The pump and motor together placed under the water. In the submersible solar water pump system, water is generally drawn from a bore well or in some cases a surface water source using a floating platform.



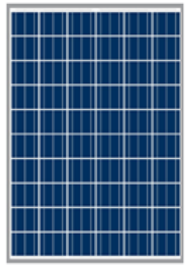
Submersible pump to lift water from a borewell



Submersible pump installed on a float to lift water from a surface water source

Different components of solar water pumping system

- PV Modules
- Pump motor
- Pump drive (MPPT/VFD)
- Mounting structure and tracking system
- DC rated circuit breakers/ disconnects
- Earthing system and conductor
- Lightning protection system
- Surge protection device
- Combiner box rated with IP 65 and UV resistant
- DC Cables
- Water level sensor, float switch

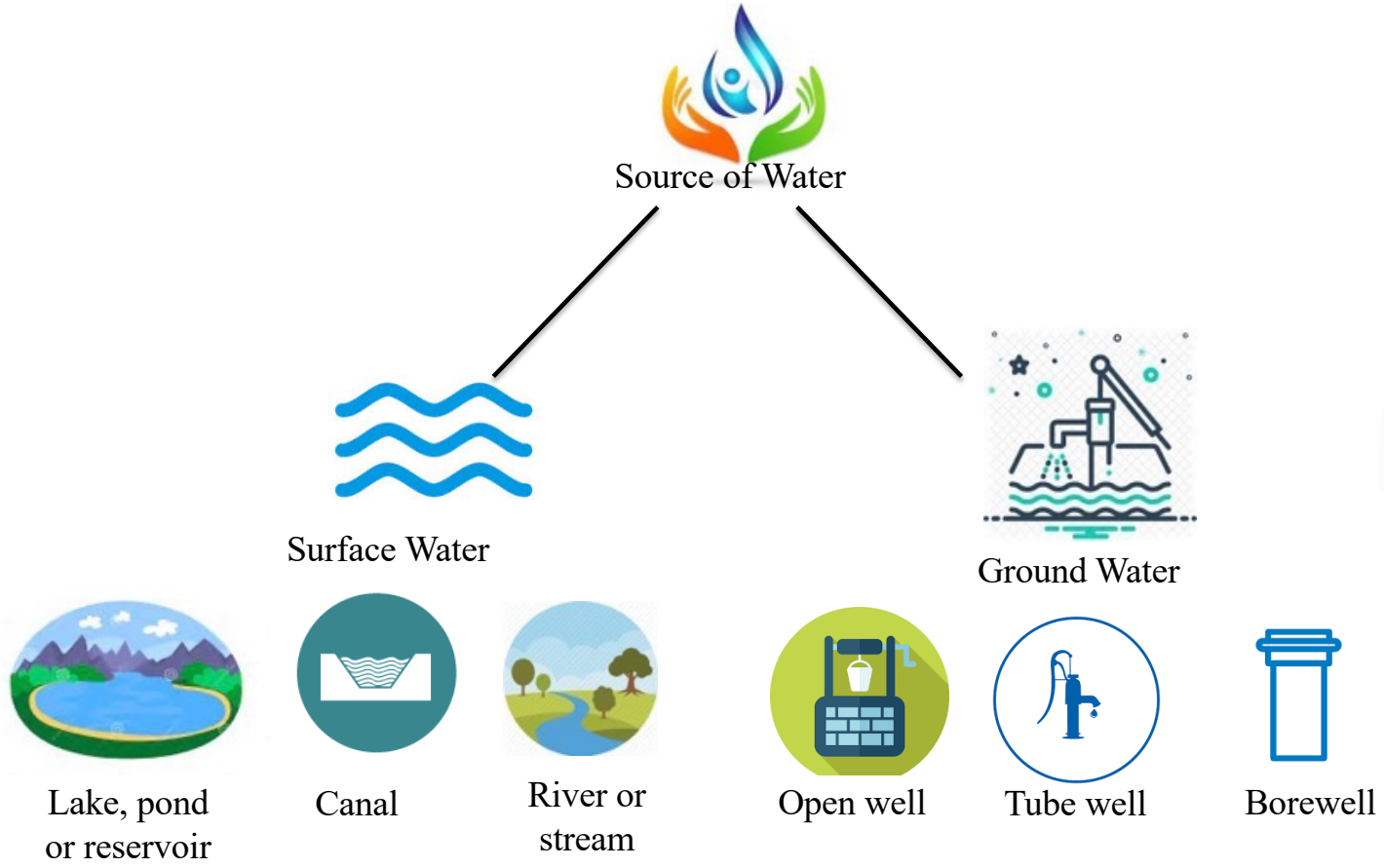







SOURCE OF WATER AND WATER DEMAND ASSESSMENT

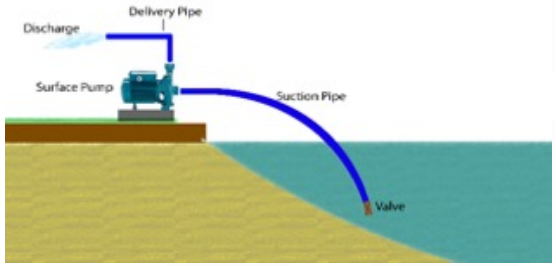
Source of water



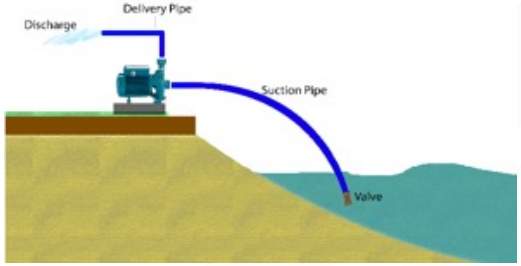
Source of water

Important aspects of surface water when used for pumping

- Level of water surface and seasonal variation – direct impact on pump performance and quantity of water delivered
- Quality of water – mineral content, abrasive particle content – impact on pump life, threat to health, crop growth, soil quality
- Possible impact on water sources due to flood, rain, erosion, draught – contamination, muddy water, sewage water, sedimentation, erosion



Water level in wet season

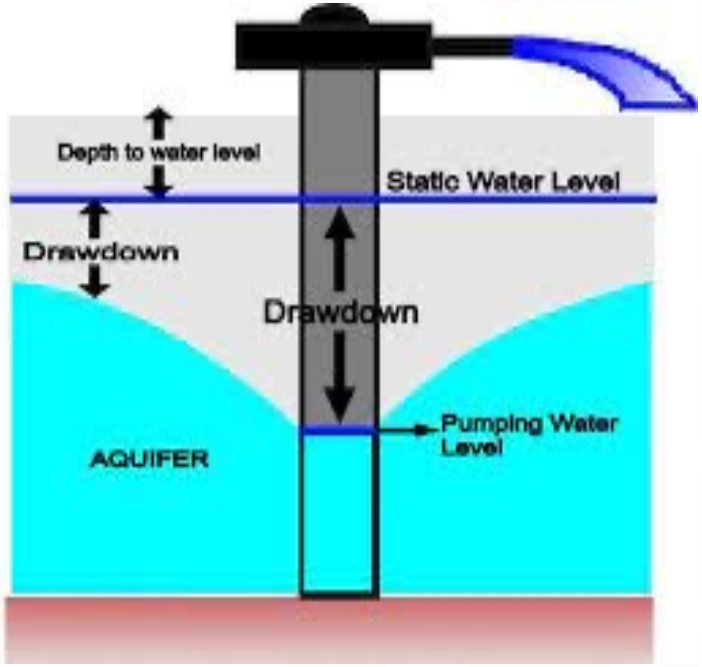


Water level in dry season

Source of water

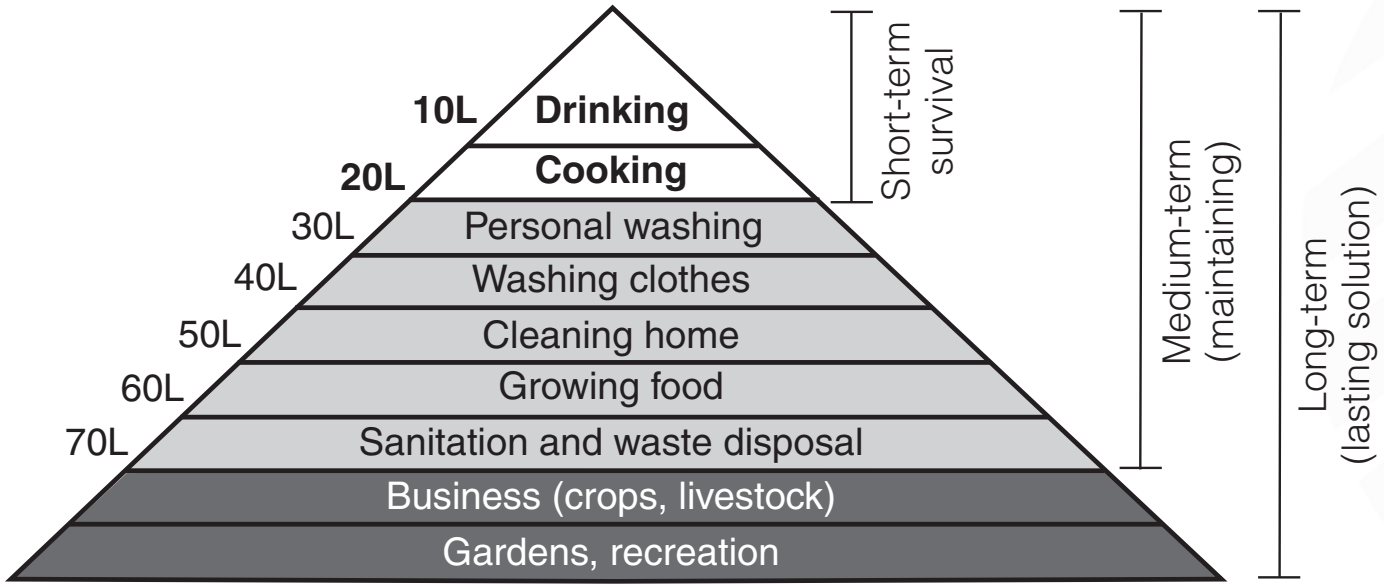
Important aspects of ground water when used for pumping

- Depth of water in well due to seasonal variation – direct impact on pump performance and quantity of water delivered
- Well diameter – Open well or bore well diameter determines drawdown, water yield (how much water can be extracted at a time) and decide what pump can be used.
- Quality of water – mineral content, abrasive particle content – impact on pump life, threat to health, crop growth, soil quality



Water demand assessment

The amount of water required depends on for what activities water is used and priorities of such activities. Typical water demand and hierarchy of water requirements (after Maslow's hierarchy of needs) has been presented in the Figure below.



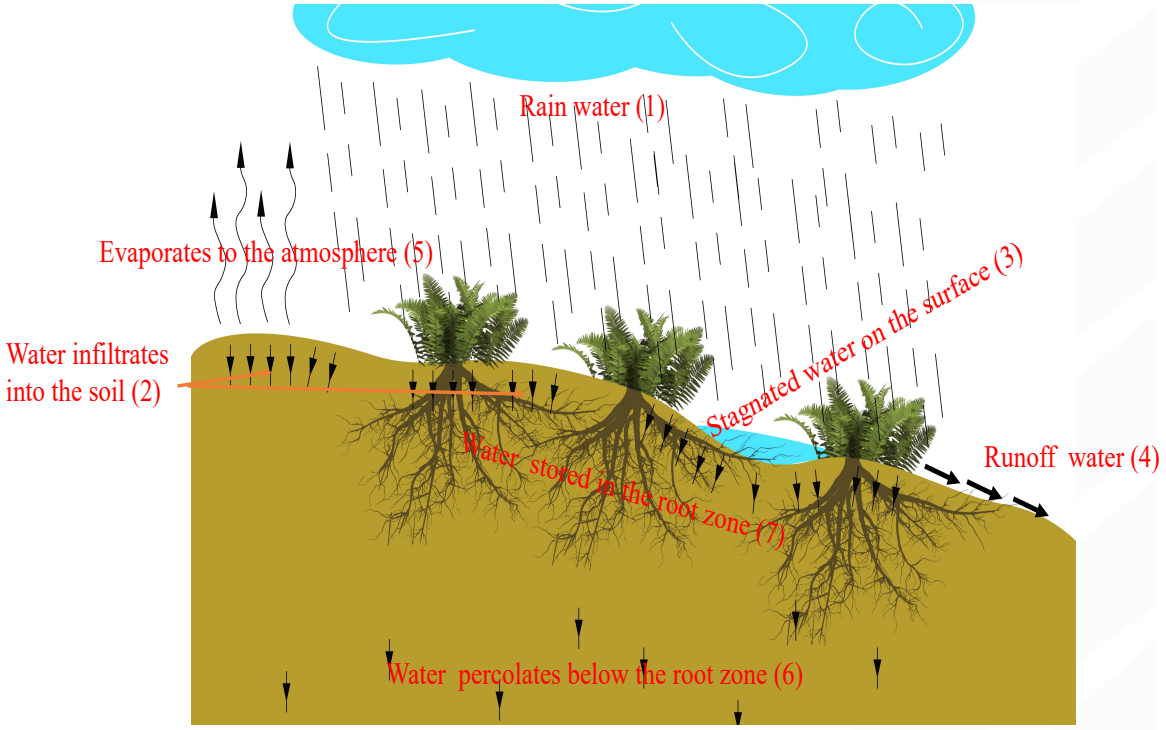
Hierarchy of water requirements (after Maslow's hierarchy of needs)

Water demand assessment

Water demand assessment for irrigation:

The water demand for irrigation is determined by a number of factors and variables. The most important factors that determine the water demand for irrigation are:

- Type of crop and growth cycle
- Climatic conditions
- Type and condition of soil
- Land topography
- Water management system
- Water distribution system efficiency



SELECTION OF PUMPS AND SYSTEM DESIGN

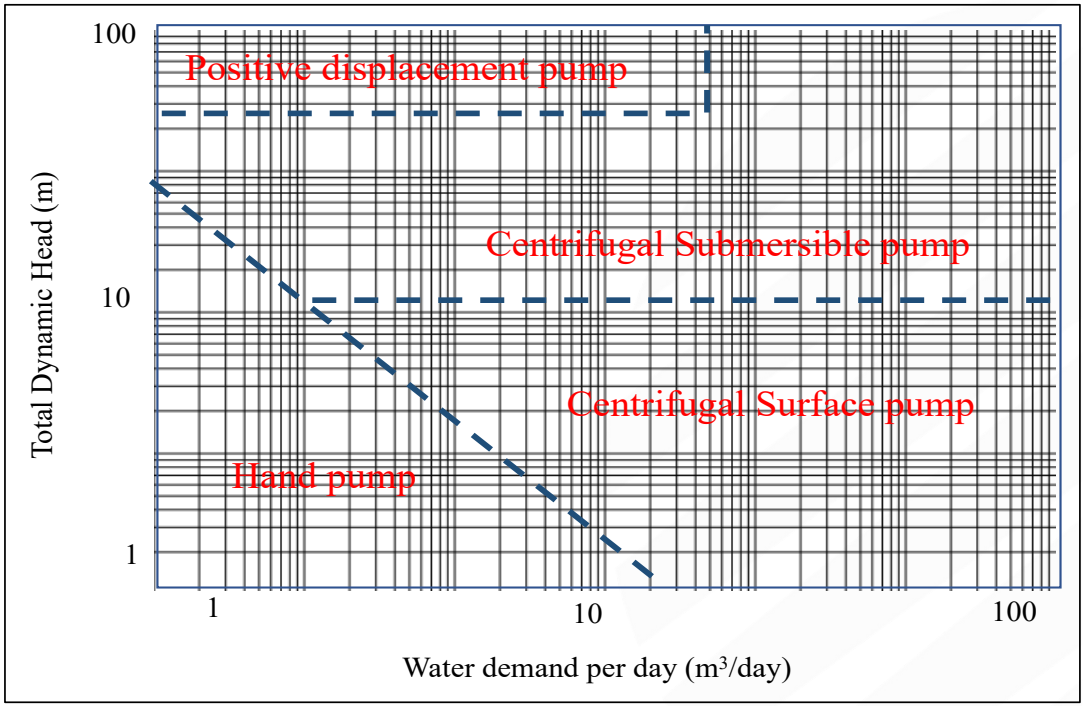
Selection of pump

Primary Requirement for pump selection

1) Total Dynamic Head
2) Pump flow rate
3) Safe yield of the borehole - Peak flow rate must be lower than the safe yield

Supplementary Considerations for pump selection

1) The diameter of the borehole
2) Abrasive particles in the water
3) Direct coupled vs battery coupled
4) Fixed array vs sun position tracker
5) DC motor vs AC motor



The safe yield of borehole is the total quantity of water that can be drawn out from the borewell without dropping the water level in the well exposing the suction point of the pump into air.

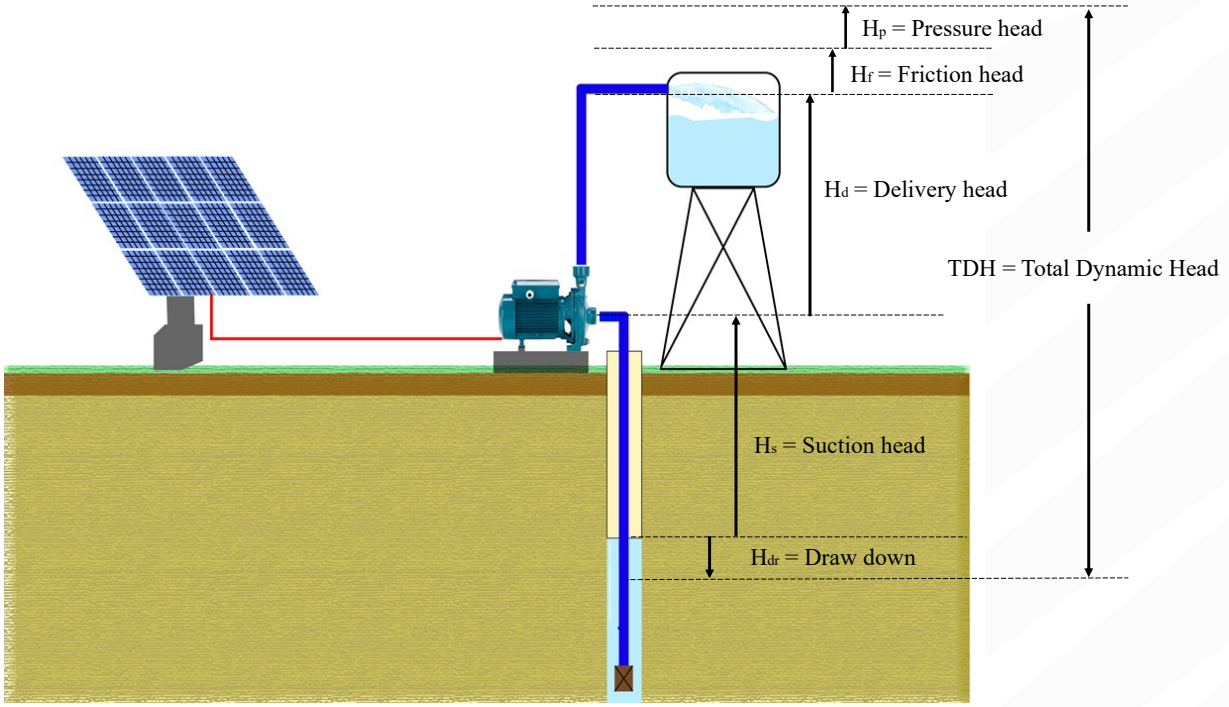
Method of calculating total dynamic head

Calculate Total Dynamic Head (TDH):

The final total head the pump must be able to deliver at the desired rate of pumping, including all the previous heads.

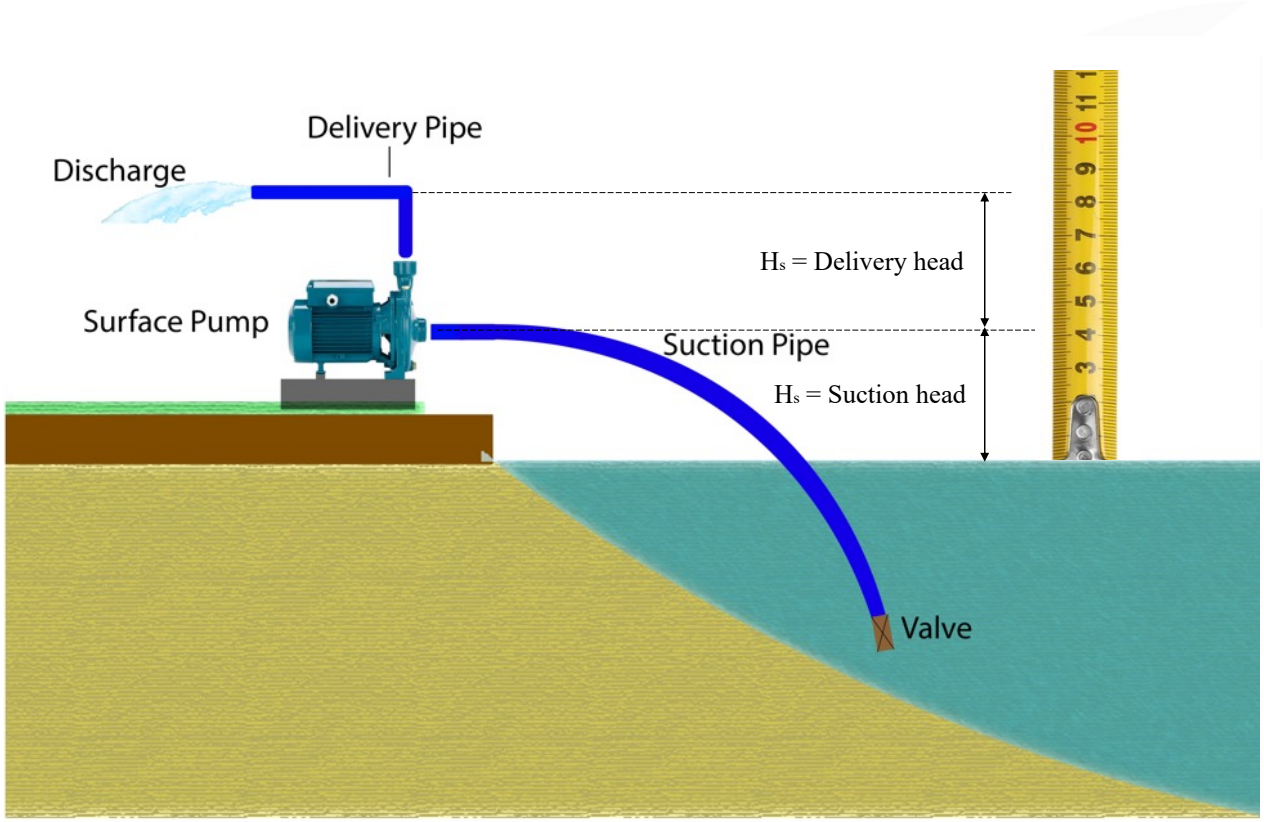
$$Total\ Dynamic\ Head\ (TDH) = SuctionHead\ (H_s) + Deliver\ Head\ (H_d) + Pressure\ Head\ (H_p) + \ Friction\ Head\ (H_f) + Draw\ Down\ (H_{dr})$$

$$= \ H_s + H_d + \ H_p + \ H_f + H_{dr}$$



Method of calculating total dynamic head

1. Determining suction head
2. Determining delivery head
3. Determining draw down
4. Determine pressure head
5. Determining friction head



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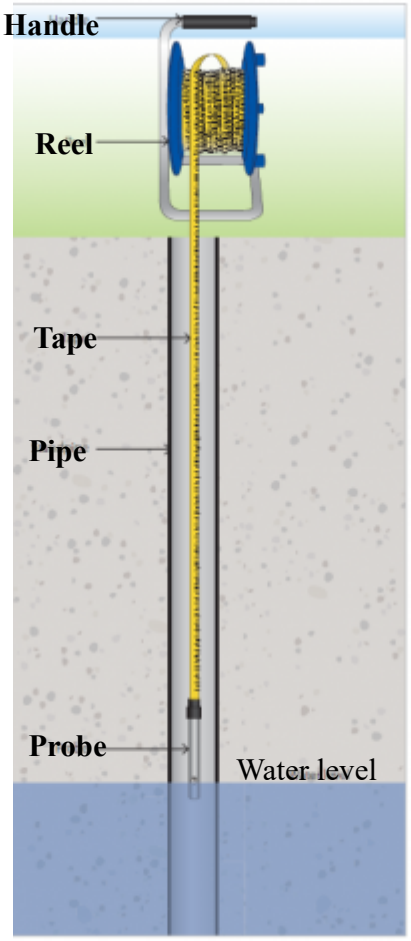
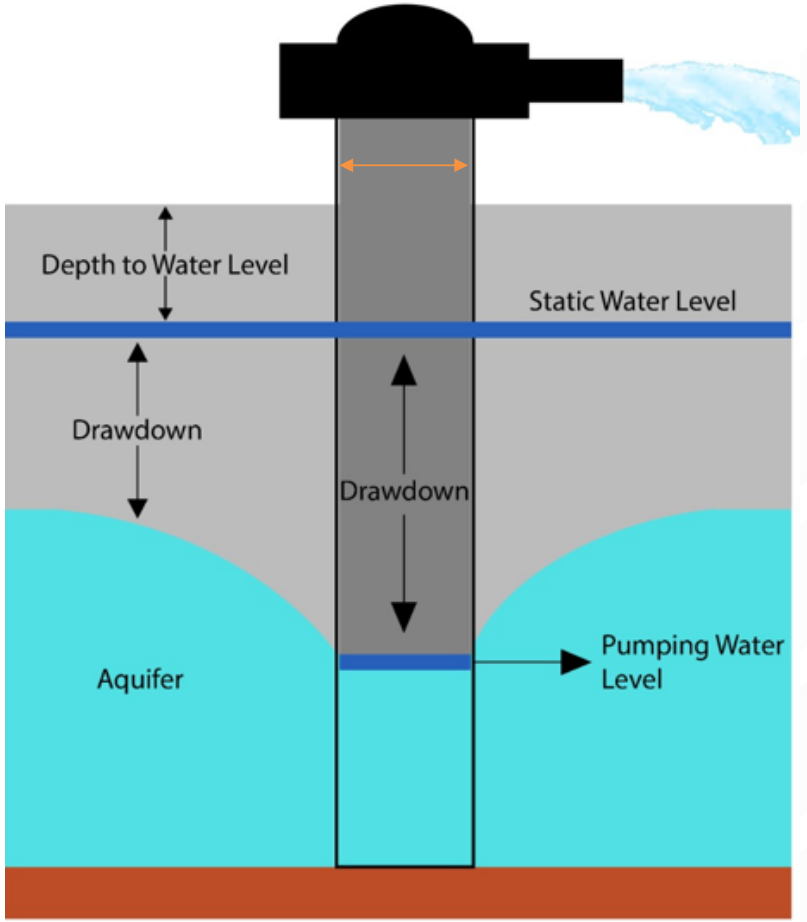
Dipmeter/ water level meter



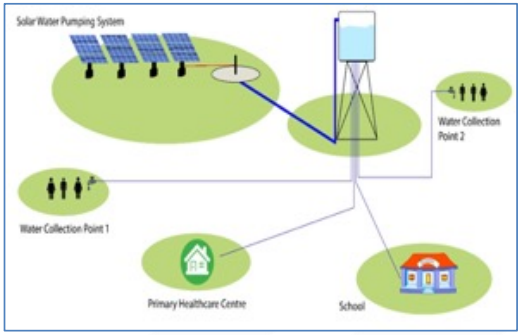


Method of calculating total dynamic head

1. Determining suction head
2. Determining delivery head
3. Determining draw down
4. Determine pressure head
5. Determining friction head

$$Pressure\ Head\ (meter) = \frac{10\ x\ Pressure\ (kg/m^2)}{Specific\ Gravity}$$

Irrigation Method	Typical head (m)
Open channels/ furrows irrigation	0.5 - 1
Flood irrigation	0.5
Drip / Trickle irrigation	1 - 2
Sprinkler irrigation	10 – 20



Method of calculating total dynamic head

1. Determining suction head
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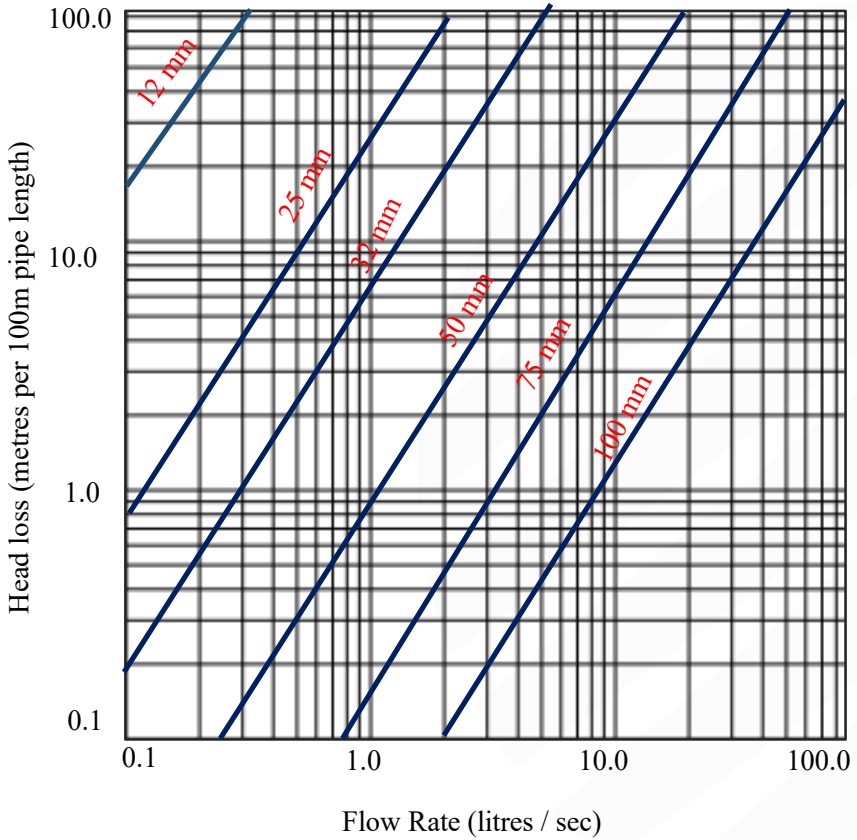
5. Determining friction head

Determining friction head using friction loss chart



Friction head is calculated in two steps:

Step 1: First the equivalent meter of head due to fittings is calculated. Then this length is added to the actual length of pipe, to give the total equivalent length of the pipe.

Step 2: The friction loss equivalent meter of head are the computed for this total length, and added to the true vertical displacements of suction and discharge head and draw down to give the final total head of the system.

Method of calculating total dynamic head

Head Loss (feet/meter) / 100 (feet/meter) Pipe Due to Friction for High Density Polyethylene (HDPE) Pipes with Roughness Co-efficient (C) value of 150

Flow (GPM)	Flow (LPS)	Pipe Diameter (Inch/ mm)								
		½" (13mm)	¾" (19mm)	1" (25mm)	1¼" (32mm)	1½" (38mm)	2" (50mm)	2½" (63mm)	3" (75mm)	4" (100mm)
0.5	0.03	0.8	0.1							
1	0.06	2.9	0.4	0.1						
2	0.13	10.5	1.5	0.4	0.1					
3	0.19	22.2	3.1	0.8	0.3	0.1				
4	0.25	37.9	5.3	1.3	0.4	0.2				
5	0.32	57.2	7.9	2	0.7	0.3	0.1			
10	0.63		28.6	7.1	2.4	1	0.2	0.1		
15	0.95		60.6	14.9	5	2.1	0.5	0.2	0.1	
20	1.26			25.4	8.6	3.5	0.9	0.3	0.1	
30	1.89			53.8	18.2	7.5	1.8	0.6	0.3	0.1
40	2.52			91.7	30.9	12.7	3.1	1.1	0.4	0.1
50	3.15				46.7	19.2	4.7	1.6	0.7	0.2
60	3.79				65.5	26.9	6.6	2.2	0.9	0.2
70	4.42				87.1	35.8	8.8	3	1.2	0.3
80	5.05					45.9	11.3	3.8	1.6	0.4
90	5.68					57	14.1	4.7	2	0.5
100	6.31					69.3	17.1	5.8	2.4	0.6

Method of calculating total dynamic head

Friction Loss in Pipe Fittings							
Steel/Copper equivalent feet of pipe caused by joint							
Fitting	Diameter (Inch/ mm)						
	½" (13mm)	¾" (19mm)	1" (25mm)	1¼" (32mm)	1½" (38mm)	2" (50mm)	2½" (63mm)
90° Standard Elbow	1.6	2.1	2.6	3.5	4	5.5	6.2
90° Long Elbow	1	1.4	1.7	2.3	2.7	4.3	5.1
90° Street Elbow	3	3.4	4.4	5.8	6.7	8.6	10.3
45° Standard Elbow	0.8	1.1	1.4	1.8	2.1	2.8	3.3
45° Street Elbow	1	1.8	2.3	3	3.5	4.5	5.4
Square Elbow	3	3.9	5	6.5	7.6	9.8	11.7
Standard T Flow Run	1	1.4	1.7	2.3	2.7	4.3	5.1
Standard T Flow Branch	4	5.1	6	6.9	8.1	12	14.3
Gate Valve - Open	0.7	0.9	1.1	1.5	1.7	2.2	2.7
Plastic equivalent feet of pipe caused by joint							
Fitting	Diameter (Inch/ mm)						
	½" (13mm)	¾" (19mm)	1" (25mm)	1¼" (32mm)	1½" (38mm)	2" (50mm)	2½" (63mm)
90° Standard Elbow	4	5	6	7	8	9	10
Standard T Flow Run	4	4	4	5	6	7	8
Standard T Flow Branch	7	8	9	12	13	17	20

Method of calculating pump peak flow rate for safe yield of borehole

$$Required\ pump\ flow\ rate\ (m^3 per\ day) = \frac{Daily\ water\ volume\ required\ per\ day\ (m^3)}{Peak\ sun\ hour\ per\ day\ (Hour)} = \frac{v}{PSH}$$

Example:

Water Demand (m^3/day)	Solar Radiation (Peak Sun Hour)	Rate (m^3/Hour)	Safe yield
10m^3/ day	4.5kWh/m^2/day	2.22 m^3 per hour	> 2.22 m^3 per hour
20m^3/day	5kWh/m^2/day	4.00 m^3 per hour	> 4.00 m^3 per hour
40m^3/day	6kWh/m^2/day	6.67 m^3 per hour	> 6.67 m^3 per hour

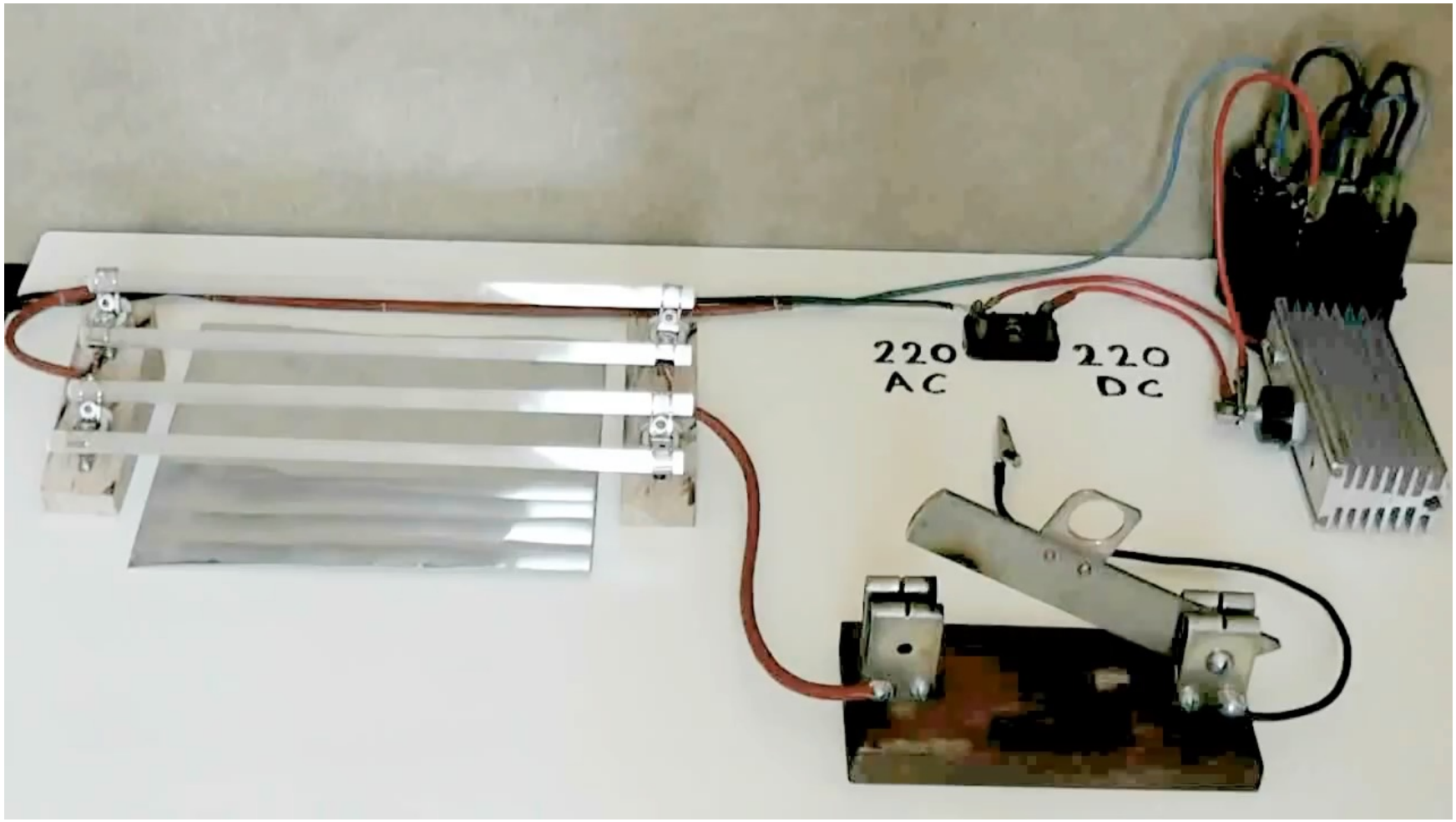
SAFETY ASPECTS OF INSTALLATION OF SOLAR WATER PUMPING SYSTEM

Personnel Health and Safety

- In a solar water pumping system, multiple numbers of PV modules are connected in series, may produce a “deadly” DC voltage 120 V or more. Similarly, the output of a VFD/ control will be 230V or 415V AC.
- Even a lower DC voltage can be cause electric shock when the skin is wet and sweating and the person is not wearing protective gear.
- In the event of any fault or leakage, any metallic part of a solar water pumping system can potentially cause severe electric hazards in the form of shock, arcing and fire.
- Only trained people in solar PV installation are to be engaged to install, operate and maintain electrical components and equipment in a grid connected PV system.
- Apart from electrical safety, the other safety issues while installation and maintaining a solar pump are:
  - Injuries from lifting and installing the structure, motor-pump, pipes and VFDs
  - Exposure to the Sun
  - Insect bites – some insect may be poisonous
  - Cuts and bumps
  - Thermal burns

System and equipment safety

DC arc is cause of fire in solar system and main reason for failure in the electrical system



System and equipment safety

DC arc is cause of fire in solar system and main reason for failure in the electrical system

Causes of DC arc – Summary

- Loose joints due to poor installation practice or poor quality connectors or corrosion over time
- Insulation degradation over time due to UV exposure, changes in temperature (hot – cold), aging
- Damage to insulation by rodents, insects, birds, monkeys
- Damage to insulation during installation O&M or other works at the site
- Water ingress to cables, conduits, connectors, isolators due to poor installation practice
- Water ingress to DC isolators due to degradation of seals over time
- Water ingression to connector due to loose glands
- Water ingress to pump drive/ VFD
- Water ingress to solar module or junction box

System and equipment safety

Damaged DC cable and connector

System and equipment safety

Loose connection at module junction box & connector

System and equipment safety

Fire in combiner box

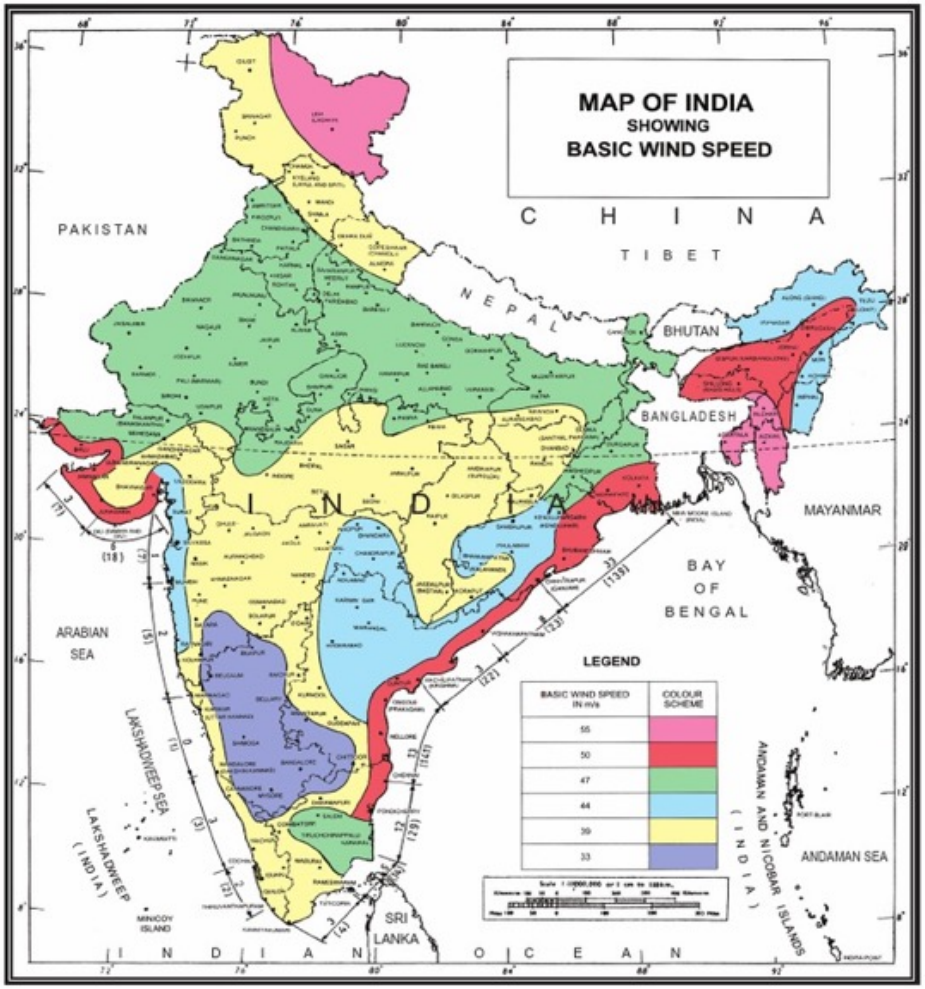
Mounting structure safety

Mounting structure safety

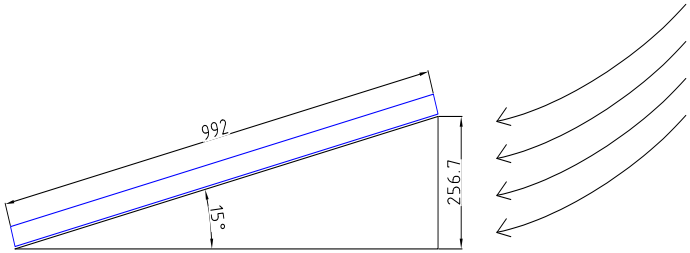
Definition of Basic Wind Speed as per IS 875 Part 3:

Three-second gust speed at 10m (33ft) above the ground in open terrain.

The wind shall be assumed to come from any horizontal direction.

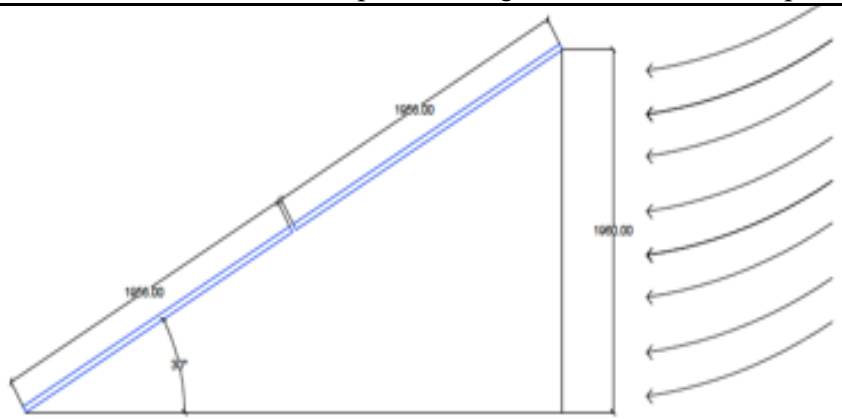


Mounting structure safety



~ 410kgf at 47m/s wind speed for a 10m wide table

Wind impact on single module in landscape configuration



~ 3100kgf at 47m/s wind speed for a 10m wide table

Wind impact on two modules in portrait configuration

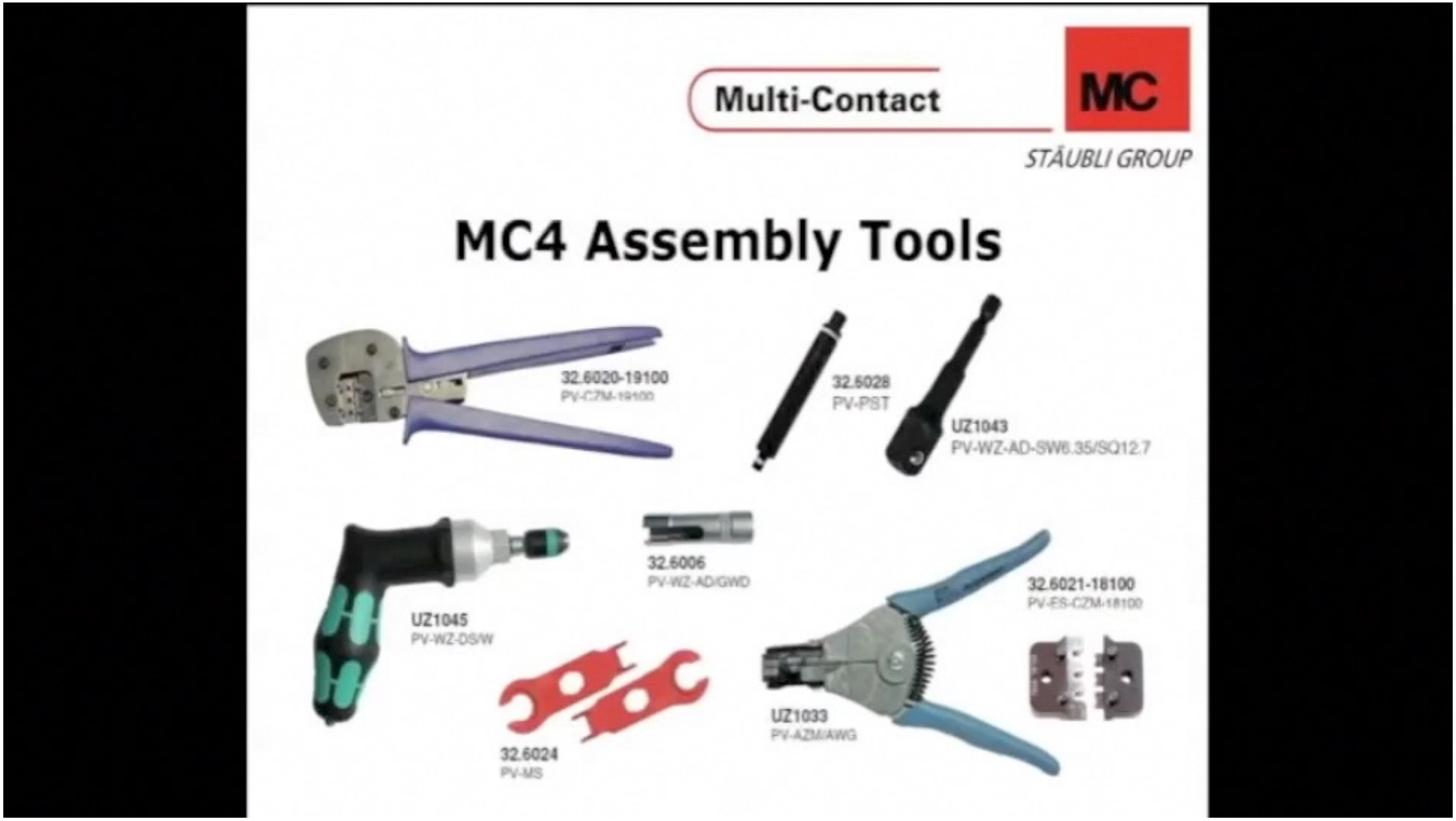
INSTALLATION OF SOLAR WATER PUMPING SYSTEM

System Installation – General instruction

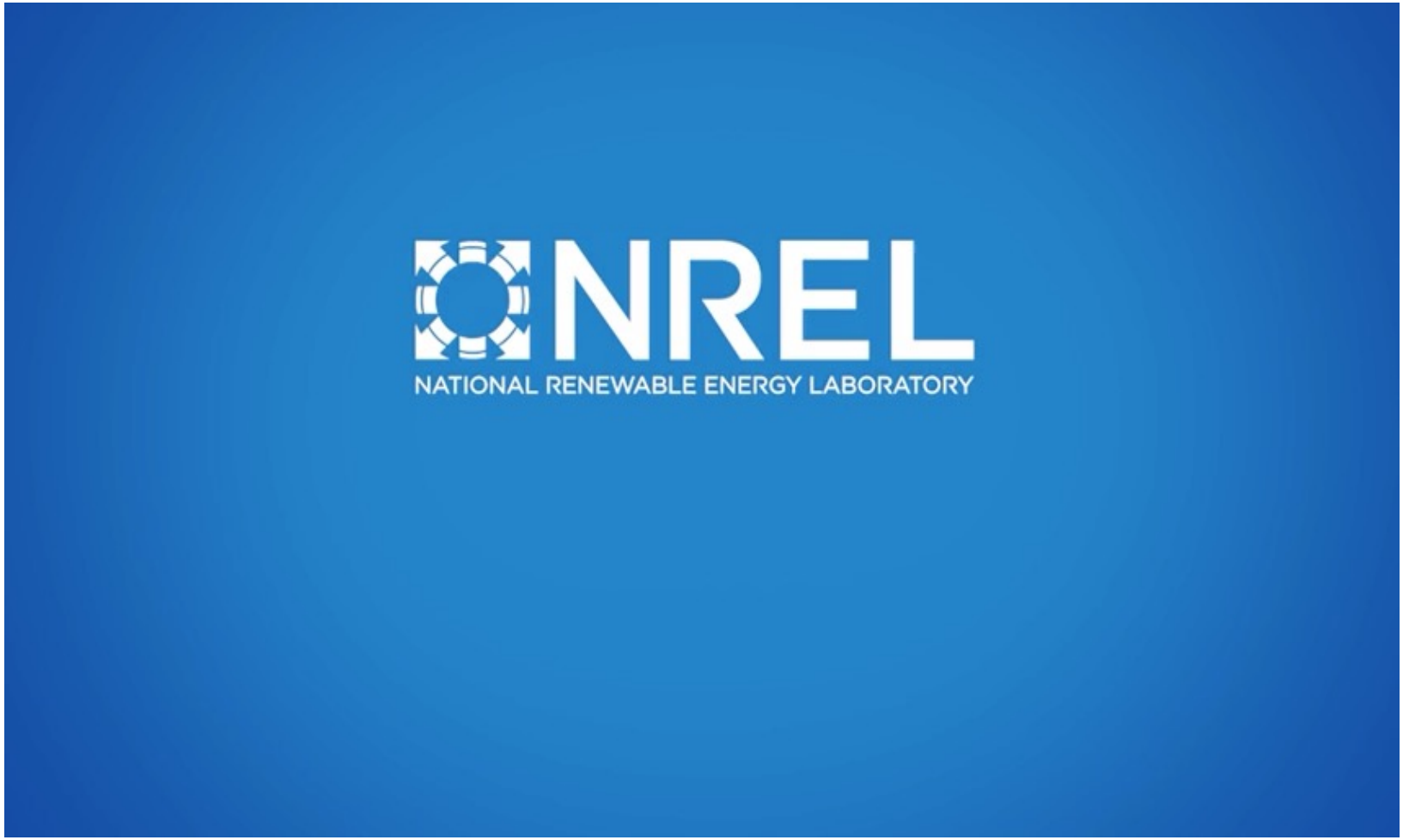
1. **General instruction**
   - Use of appropriate tools and equipment - required for PV system, water pump and pipe installation work
   - Consideration of varying water levels – to ensure that pump does not run dry at any time
   - Protect the pump inlet – from sand and dirt
   - Earthing – Ensure that earthing system intact its continuity and it is connected to ground (earth)
   - Pipe length, diameter and friction loss – ensure that size of pipes are selected according to water flow rate to minimise friction loss
   - Protect the control equipment – from dust, water and sunlight
   - Protect the well and PV array – from animals, people and natural calamities

Tools for Installation

Tools for Installation



Installation of PV array



Installation of PV array

- Install modules in a shadow free area as shadow will result into poor performance and it can also damage the PV modules

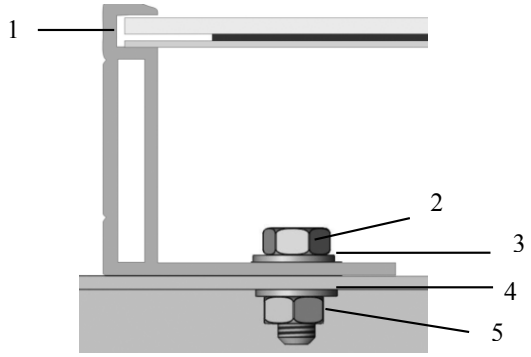
- PV modules must be handles carefully as instructed by the manufacturer as wrong handling of PV modules may cause micro cracks

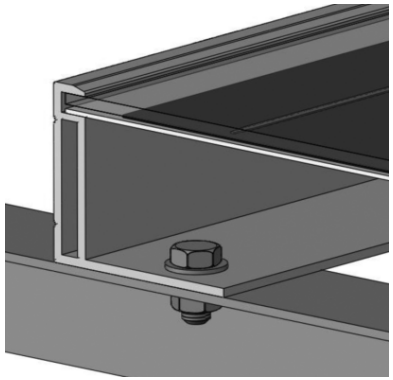
Installation of PV array

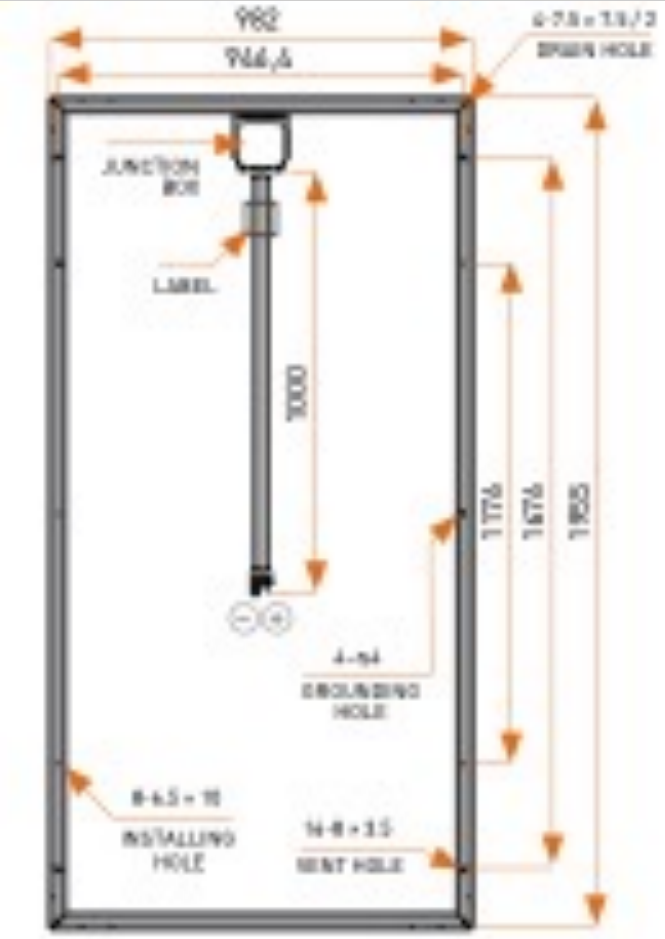
Modules are mounted either using

A. M8 bolts placed through the mounting holes or

B. Using module clamps







1) Aluminium Frame
2) M8 Stainless Bolt – torque 16 – 20 N. m
3) Flat Stainless Washer – 1.8 mm thickness
4) Spring Stainless Washer
5) HEX Stainless Nut

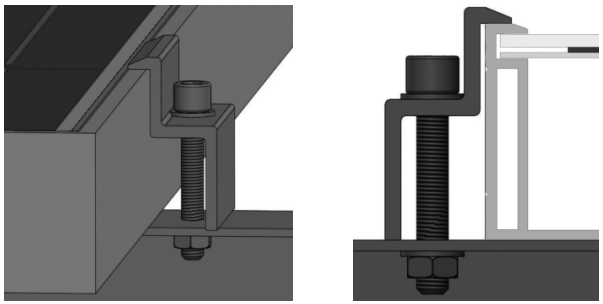
Installation of PV array

Modules are mounted either using

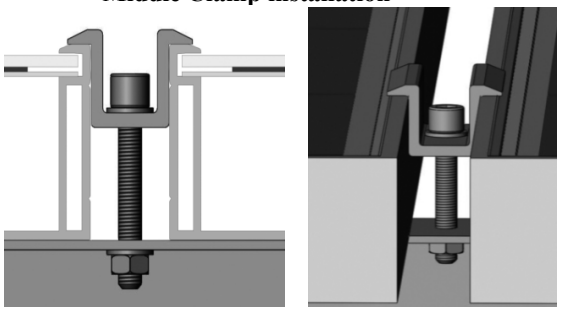
A. M8 bolts placed through the mounting holes or

B. Using module clamps

End Clamp installation



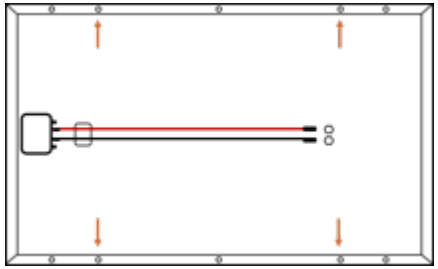
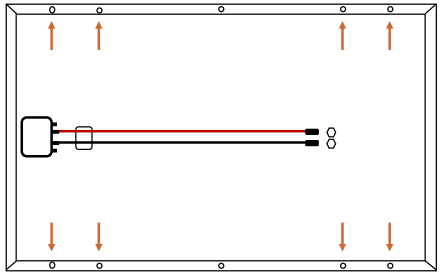
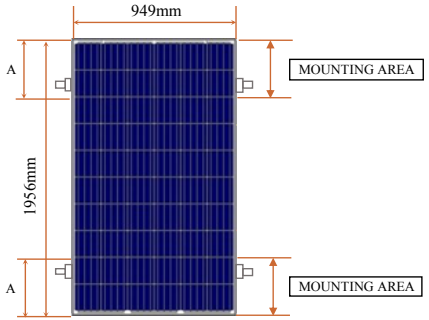
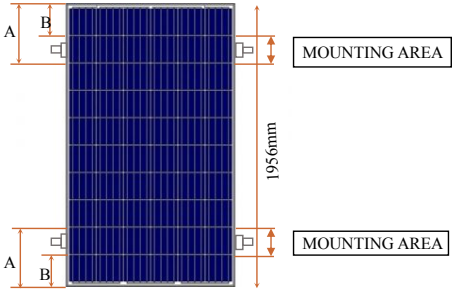
Middle Clamp installation



- Clamps should have an EPDM or similar insulating washer,
- Fixing bolt should be at least M6.
- The clamp must overlap the module frame by at least 7mm but not more than 10 mm (to avoid contact with front glass)
- Use at minimum 4 clamps to fix modules on the mounting rails
- The module frame is not to be modified under any circumstances
- At least 4 clamps should be used when modules are installed in portrait or landscape.
- For high wind areas, additional clamps or longer clamp size should be used to ensure that modules can bear the load.
- Applied torque for M6 - 9 N. m
- Applied torque for M8 -16 - 20N. m

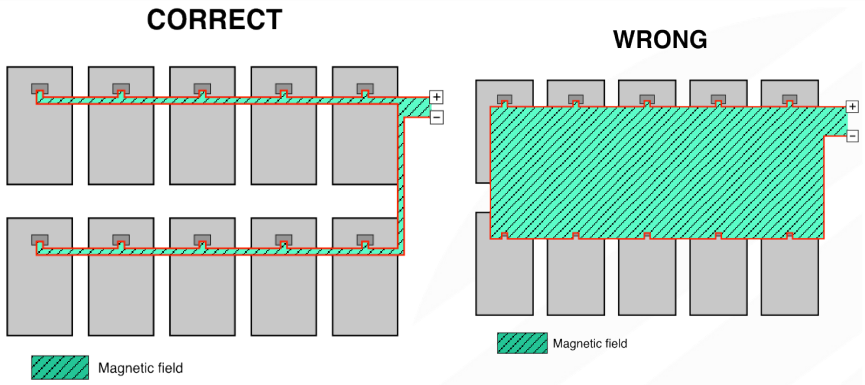
Installation of PV array

In the very high damage risk wind zone, the mid-clamps used for attaching the modules must be longer than 50mm (2 inches) in length and it is recommended to use 3 rails while installing in portrait position. In a large system, consideration shall be given for using an end clamp for every fourth module so if one does become loose, then only a few other modules would be affected, not necessarily the whole array.

Type of Mounting Method	240kg/m^2 Wind Pressure	540kg/m^2 Wind Pressure
Bolt type mounting system	 Use 4 mounting holes	 Use eight mounting holes
Clamping on Portrait position	 A = 489mm	 A = 489mm, B = 244.5mm

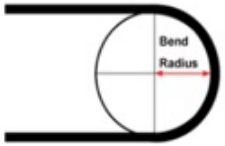
Cabling and Interconnections

- All cablings shall be undertaken in a neat and tidy manner.
- The cables must be protected from mechanical damage.
- All cables used in the installation should be securely fixed in place to minimise any movement of the cable.
- Minimize the area of conductive loops to reduce the magnitude of lightening-induced overvoltage as shown in the figure on top
- Keep bending radius of cable more than 43 mm or as recommended by module manufacture. Maintain correct cable routing as shown in the figure at bottom



Good Practice

Bad Practice



The minimum bending radius cables should be 43mm

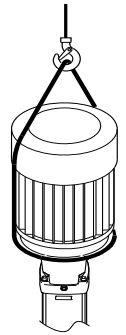
Incorrect routing of cable

Correct routing of cable

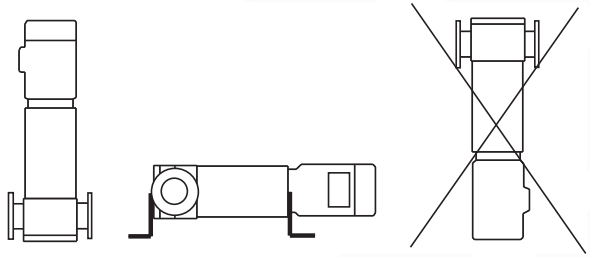
Installation of motor-pump unit

Surface motor-pumps:

- Surface pumps can provide limited suction head and it works effectively when suction head is minimum.
- It is very important to ensure that there is no leakage in the suction side as the pump will not work even for a very small leakage in suction pipe.
- The inlet to the suction pipe must be free from sediment, floating debris etc. which otherwise damage the pump. Follow manufacturer's installation instruction manual to install the pump.
- **Lifting of pump-motor:** The pump unit should not be lifted or supported by its cable attached to it or to the pump shaft. A rope or strap should be attached to a suitable point to lift the pump to carry from one place to another.



Use strap to lift the pump



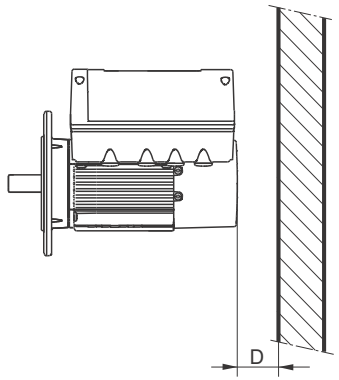
Correct position of pump installation

Source: Grundfos

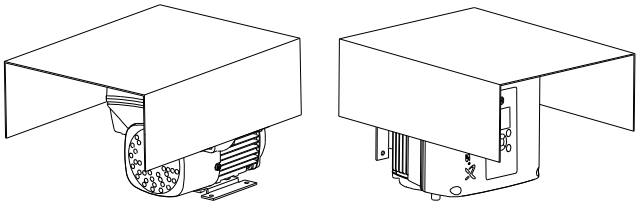
Installation of motor-pump unit

Surface motor-pumps: Pump Location:

- Locate the pump in a dry, well-ventilated area which is not subject to extreme variation in temperature.
- The surrounding of the motor must be free for ventilation to prevent overheating.
- There should be a minimum clearance of 150 mm from any obstruction and adequate free space should be kept so that the motor-pump can be removed for repair. The pump should be installed as close as possible to the water source to reduce friction loss in pipes.



Maintain minimum gap



Correct way of installing pump cover

Source: Grundfos

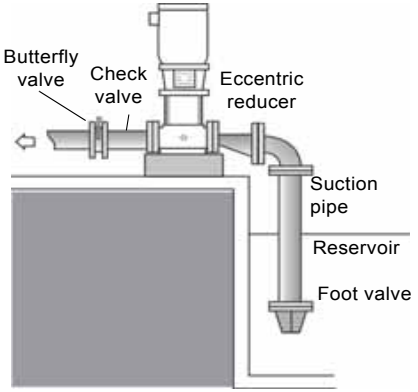
Installation of motor-pump unit

Surface motor-pumps: Suction pipe installation

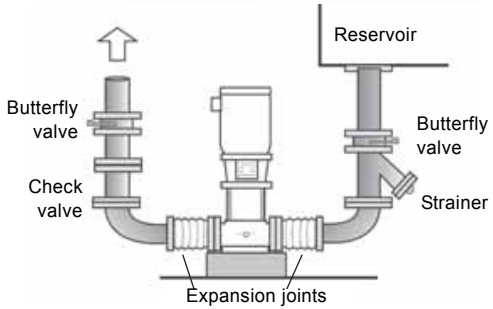
- The size of the suction pipe must be as recommended by the pump manufacturer and it should be straight and short as possible to minimize friction loss and improve net positive suction head available (NPHSA).

- Avoid using unnecessary fittings, valves or accessory items.

- In case of a flooded suction, use butterfly or gate valves in the suction line to isolate the pump (figure at bottom)



Suction lift



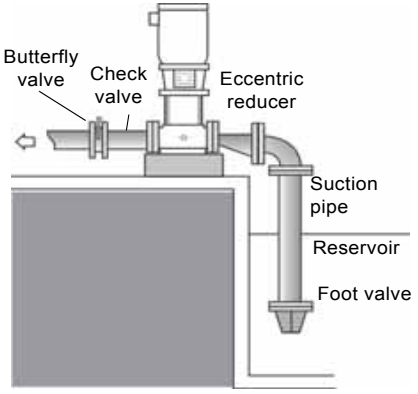
Flooded suction when water source is above the pump

Source: Grundfos

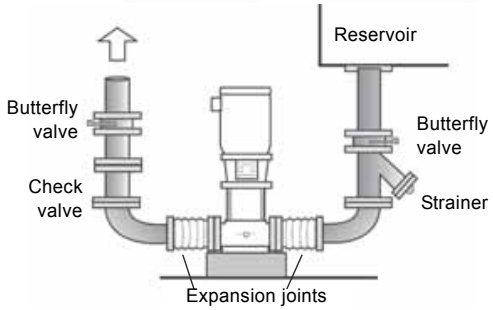
Installation of motor-pump unit

Surface motor-pumps: Discharge pipe installation

- Pipe, valves and fittings should the same diameter as the discharge pipe to reduce friction losses in pipes.
- The pressure rating of discharge pipe, valves and fittings must be equal to or greater than the maximum system pressure.
- It is advised to install a check valve and an isolating valve in the discharge pipe.
- Avoid high pressure loss fittings, such as elbows or branch tees directly on either side of the pump.
- The piping should be adequately supported to reduce thermal and mechanical stresses on the pump.



Suction lift



Flooded suction when water source is above the pump

Source: Grundfos

Installation of motor-pump unit

Surface motor-pumps: Discharge pipe installation

- Never install the pump at the lowest point of the system due to the natural accumulation of dirt and sediment.
- If there is excessive sediment or suspended particles, a strainer or filter should be used.
- A check valve may be required on the discharge side of the pump to prevent the pump's inlet pressure from being exceeded.
- All electrical connection to be made as per installation manual connection diagrams.
- The motor must be earthed and protected against indirect contact in accordance to prevent from electrical shock.

Pump suction strainer

Installation of motor-pump unit

Submersible motor-pumps:

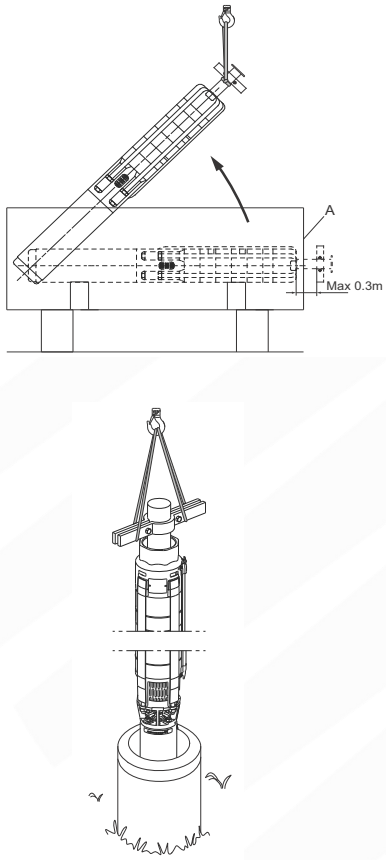
- Submersible motor-pump unit will be installed under water therefore, all cable connections and seals should water tight and fixed as per the instruction in the installation guide provided by the manufacturer.
- Depending on motor type and source of water, the pump can be installed either vertically or horizontally.
- Manufacturer's instruction must be followed as not all motors suitable for horizontal installation

Submersible water pumps

Installation of motor-pump unit

Submersible motor-pumps: Lifting and lowering the pump

- Do not lower or lift the pump by means of the motor cable.
- Check the borehole using an inside calliper before lowering the pump to ensure that the pump will fit comfortably to the borehole.
- Ensure that the motor cable and the submersible drop cable is not damaged while lowering the pump into the borehole.



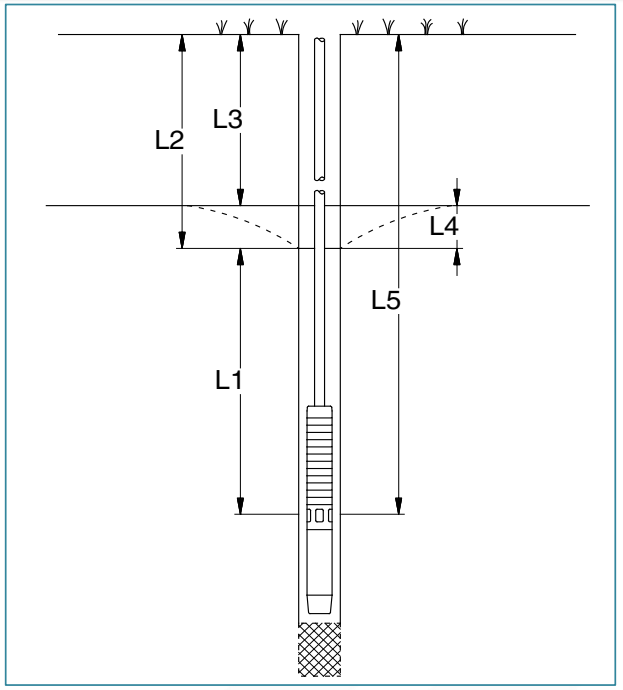
Lifting submersible pumps

Source: Grundfos

Installation of motor-pump unit

Submersible motor-pumps: Installation depth

- The dynamic water level (water level after draw down) must always be above the suction interconnector of the pump.
- Maintain a minimum installation depth of 0.5 m below dynamic water level as shown in the figure or as instructed by the manufacturer
- It is recommend that the pump is installed so that the motor part is above the well screen in order to ensure optimum cooling



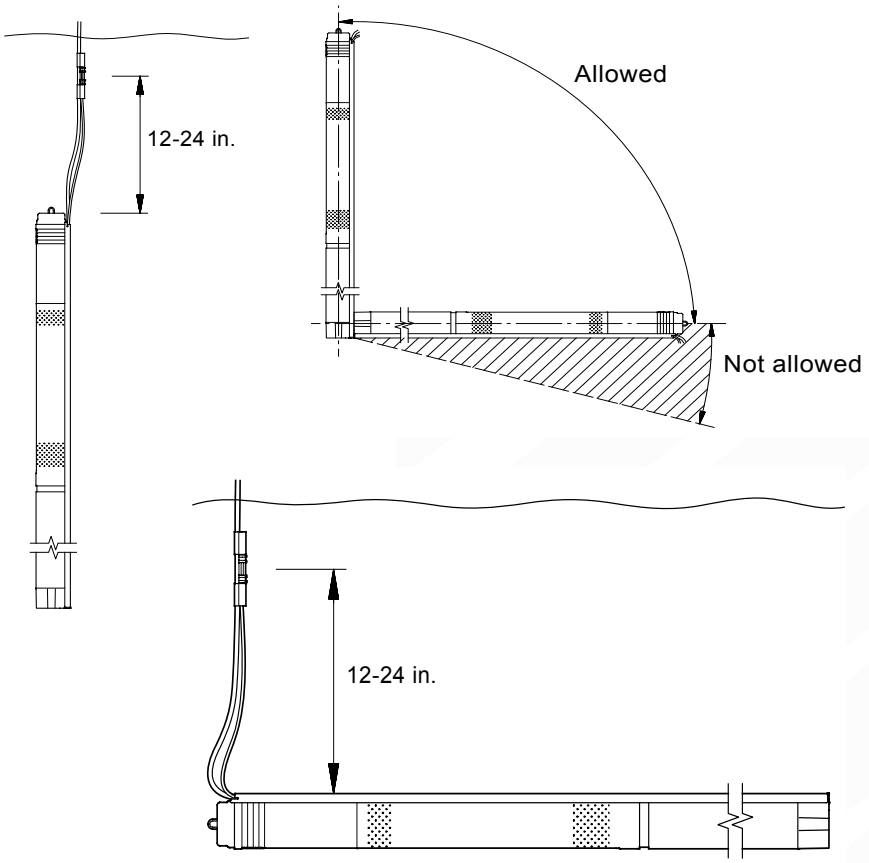
- L1: Minimum installation depth (Recommend minimum 0.5 m)
- L2: Depth to dynamic water level
- L3: Depth to static water level
- L4: Drawdown
- L5: Installation depth.

Source: Grundfos

Installation of motor-pump unit

Submersible motor-pumps: Installation of pump

- If pump peak flow is greater than the safe yield of the well, ensure that a dry-run protection is included in the motor-pump system.
- If pump does not include dry-run protection, install an additional water level electrodes/ sensors with control switch to protect the pump from dry-run.
- If the pump is installed horizontally, the outlet port must never fall below the horizontal plane as shown in figure.
- After the pump has been installed, the borehole must be sealed.
- The straining wire can be locked to the borehole seal by means of wire lock



Submersible water pump position under water

Source: Grundfos

THANK YOU

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