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# SITING CONSIDERATIONS
## For Kinetic (In-Stream) Hydro Turbines

Hydrokinetic (in-stream) turbines produce electricity from the free-flowing water in a river or stream – water in motion, or the velocity (speed in a specific direction) of the water. You will get the best performance and the highest power production from a smooth, linear flow of water at high velocities. Properly siting a hydrokinetic turbine requires an understanding of energy as it relates to water, and then what influences the kinetic energy (velocity) of the water at any given point in the river.

### The Energy in Water

Work is done when a force produces movement. When discussing hydro turbines, the force is the energy in water, the work is the production of electricity, and the movement is the rotational component of the turbine – energy from the water spins the turbine rotor which then produces electricity.

The total energy available in water is the sum of the following energy forms:

- ***potential energy*** – the energy related to the location of the water. Potential is determined by the height of the water relative to a fixed point. Potential energy does not do work.
- ***pressure energy*** – the energy available when the water is under pressure. Pressure is strictly related to the depth of the water above the location. Depth is the vertical change in elevation between the inlet and the outlet in a closed system (not exposed to gravity), regardless of the horizontal distance involved.
- ***kinetic energy*** – the energy in moving water. This refers to the velocity (or speed) of the water. Velocity is speed in a specific direction.

Some important points to remember are:

1. The total available energy in a water system will always be the sum of these three components.
2. The total energy throughout the system will remain constant, reduced only by friction losses that convert some of the energy to heat.
3. The relative proportions of the three energy forms can (and will) vary throughout the system. But an increase in kinetic energy (velocity) results in a corresponding decrease in pressure energy, and vice versa, so that the total energy is always the same.
4. In a pipe (and to a to a large degree in rivers and streams) the water volume adheres to the *law of continuity* – the discharge volume will always equal the input volume at the

front end, adjusted only by differences in the amount held in storage along the way. If a river has one water source and one outlet and no regulated dam along the way, the amount discharged will equal the amount entering the river at the source.

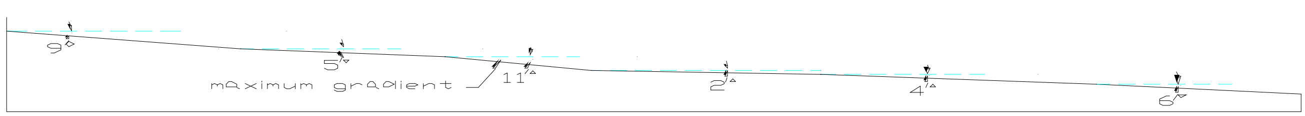
5. The force necessary to convert the energy to electricity is a combination of water pressure and water volume. These two are inversely proportional and pressure is far more effective.

The production of electricity from water always involves the two dynamic energy forms – pressure and kinetic. The difference between the pressure hydro and kinetic hydro styles pertains to the influence that each energy form has on the turbine. The pressure systems, which are the most efficient, release pressurized water inside the turbine, converting it to kinetic energy that spins the turbine rotor.

Kinetic systems, or in-stream systems, rely on the energy in the free-flowing water. This movement results primarily from the gravitational forces acting on the surface of the water. Kinetic hydro systems require much more water volume. As compared to pressurized hydro systems which utilize relative straight forward pressure-energy calculations, properly siting a hydrokinetic system requires an understanding of the dynamics of free flowing water in the complex river environment. Following is a brief discussion of some of the issues involved. The magnitude of the system you intend to install will dictate the extent to which the site and the project are engineered. Please contact our systems engineers for further detail.

<u>The gradient of the river</u>

As rivers travel to the sea, they follow the "lay of the land" (ground slope) which is constantly changing. This gradient, or slope to the river, corresponds to the ground over which it is travelling at that point. Some sections of river will have a steeper slope (often resulting in rapids) and others will have a very gentle slope (resulting in deep water pools). The steeper the slope, or gradient, the greater the velocity or current speed. The gradient of the river is the most influential factor in current velocity. The optimal location for a hydrokinetic turbine is at the steepest gradient possible without incurring excessive turbulence.




RIVER GRADIENT CROSS-SECTION

<u>The alignment of the river</u>

Just as with water travelling through a pipe, there is less friction loss (and more velocity) in a straight section of river than at a bend in the river. The most linear and stable water flow will normally be found in straight sections of river. If a bend in the river is the only option because of other considerations, the greatest velocity is in the outer portion of the bend.

These areas can have problems, though, as the current will typically tend to undercut the outer bank and the effect of the water flow patterns at the bend can result in swirling cross flows that impact velocity.

<u>The width and depth of the river</u>

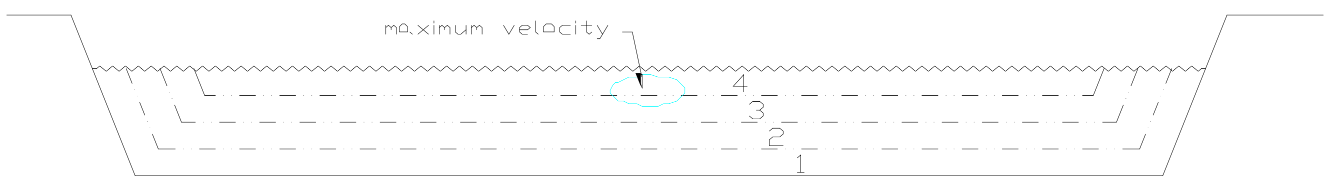
Friction is the major detriment to water velocity. Wider sections of river are generally more shallow and have a higher percentage of ground contact (river bottom and banks) than narrower, deeper sections of river. This ground contact slows down the velocity – in fact the velocity at the point of contact is essentially zero – and the areas that are in closest proximity to the bottom and banks will have the lowest velocity. Areas next to the banks can develop rotating cross flows.

<u>The contour of the river bottom</u>

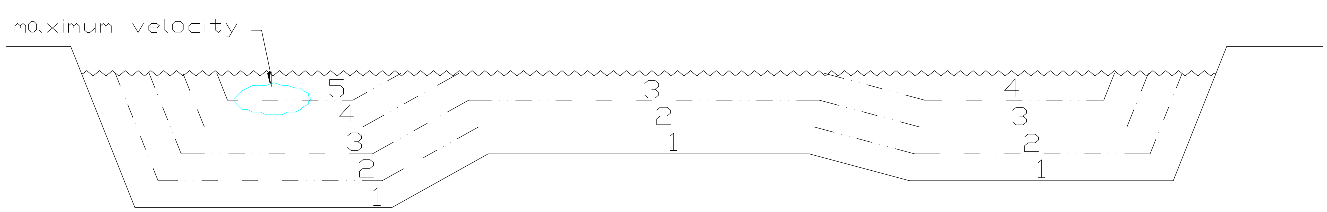
If the contour of the river bottom (and hence the water depth) is uniform across the river, the greatest current speed is going to at the point that is the farthest from all ground contact – the upper center of the river. If the contour is uneven, the greatest velocity will be in the upper center of the portion that has the greatest depth.

<u>Depth of the turbine rotor</u>

The greatest velocity will normally be in the area below the surface from 10% to 30% of the river depth at that point. If your river depth is 10 ft at that point, the greatest velocity will be between 1 ft and 3 ft below the surface. The areas of least velocity are next to the banks and at the river bottom. Ideally, the turbine rotor will fit within this 10%-30% high velocity area. If the turbine must extend beyond this range, extend the turbine below the range, but take care to avoid the turbulent area next to the river bottom.



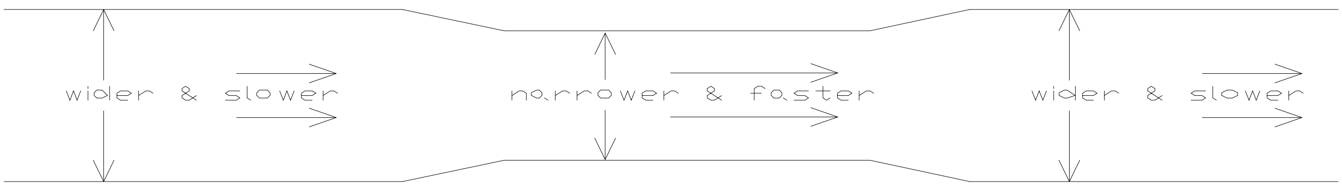

CROSS-SECTIONAL VELOCITY COMPARISON




CROSS-SECTIONAL VELOCITY COMPARISON

<u>Cross-sectional Area</u>

Remember the law of continuity from earlier. Sections of the river that have a smaller cross-sectional area will have a greater velocity. Because the same volume of water is passing through a smaller area at the same discharge rate as the larger cross-sectional areas, the water has to move through that area faster.



VELOCITY CHANGES WITH CROSS-SECTIONAL CHANGES

Discharge volume

The velocity at a given point will be greater during periods of high water (due to rainfall, snow melt, etc) than periods of low water levels. The reasons a combination of less friction – there is a higher volume of water flowing down the river relative to the ground surface contact – and increased force due to the fact that there is a larger volume of water trying to move downstream.

The roughness of the river bottom

There are very few (if any) areas with truly linear water flow. The entire cross section of the river can be considered turbulent. However, rough river bottoms (either rocky or uneven ground) increase friction and create excessive turbulence. Both friction and turbulence slow the water speed. Try to avoid siting the turbine in a shallow section of river where the turbine rotor will be exposed to excessive turbulence.

Obstacles

Obstacles or obstructions in the river create turbulence. Avoid these areas – particularly in the immediate down stream area. Typical obstructions would be bridges or rocks.

## Selecting the Site-the Water Resource

Ideally, pick a straight, narrow, and deep section of river with a relatively steep gradient that has no obstructions and a relatively smooth river bottom. Avoid excessive turbulence – the smoothness of the surface will give you a good indication. Since installing the hydro turbine in the center of the river can be difficult and a potential navigation hazard, select a section of river where the bottom contour is such that there is a deep section next to the bank. Position the turbine in the center of that deeper spot but at least one river depth from the bank. If the river depth at that point is 8 ft, the turbine should be at least 8 ft from the bank.

## Other Site Considerations

Following are other siting considerations. They are briefly addressed here. Please consult with our systems engineers as to how they will apply to your specific project.

1. Permits
IMPORTANT: Your hydro installation may require local, state, and/or federal permits. Please consult with our systems engineers for requirement details.
2. Turbine Mounting Structure
The turbine requires a mounting structure. This structure must be strong enough and secure enough to support the turbine during floods and other high water periods. The mounting structure must also allow for the turbine to be adjusted vertically as the water level in the river changes. If the turbine is to be mounted on a permanently affixed structure like a dock, the ability to adjust the turbine elevation and positioning of the turbine to avoid turbulence created by the dock are crucial. A floating boat or platform is the easiest means of providing proper positioning of the turbine but consideration must then be given to adequate anchoring of the floating structure.
3. Floating Debris
Some means must be provided to protect the turbine rotor from floating debris. A diversion rack on the upstream side of the turbine to deflect debris is common. Contact our systems engineers for recommendations.
4. Fish
Typically, rivers that are suitable for these turbines will have fish populations. While these turbines have proven to have no appreciable impact on fish populations, this is an issue that should be given careful consideration. Site permits may require specific study or monitoring to ensure that there is no negative impact on fish populations.
5. Access to the Power Grid
To avoid excessive transmission line costs, the turbine should be sited reasonably close to the electrical load or electrical grid connection. Care should be taken to ensure that National Electrical Code requirements are complied with in the inter-connect, particularly in the portion over the water.
6. Site Access
Ease of installation and maintenance dictates that the site should have reasonable access. If a pontoon boat or floating dock is used, siting the turbine close enough to shore for ramp access is beneficial.
7. Theft & Vandalism
These systems are a significant investment. It is prudent to take steps to ensure that they are protected. Equally important is to provide sufficient access protection so that children or curious individuals cannot inadvertently put themselves in harm's way.
8. River Navigation
These systems will often be in navigable waterways. When siting the turbine, it is important that the installation not conflict with transportation routes, creating a potential hazard. Often a permit requirement will be that the system be adequately lighted or otherwise marked to warn passersby of its existence and location. This requirement also applies to anchoring and electrical transmission line.

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