New York State Energy Research and Development Authority

Marine and Hydrokinetic Environmental Policy Workshop

Marine and Hyrdrokinetic Technology Background and Perspective for New York State

Final Report

December 2012

No. 12-27b

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Background and Perspective for New York State

Final Report

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NYSERDA
Report 12-27b

NYSERDA 20802A

December 2012

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INTRODUCTION

Hydrokinetic power generation from river and tidal currents represents substantial potential as a renewable energy generation resource for New York State that in some cases can be co-located with energy consumers. Technology development efforts and ongoing environmental monitoring of a permitted hydrokinetic generation pilot site in New York State, the Verdant Power Roosevelt Island Tidal Energy (RITE) Project, located in the East River in New York City is ongoing.

A major hurdle facing hydrokinetic power generation development is the environmental permitting of projects. Currently there is an evolving body of environmental policy for regulatory agencies to turn to in an effort to understand the potential environmental impacts resulting from the deployment of this technology. It is important that regulatory entities ensure an appropriate environmental review of this renewable technology in its early stages of development, but regulations and permissions should be clear and reasonable, and consistent with evolving renewable energy policy.

The NYSERDA Environmental Policy Workshop, to be conducted in May of 2012, seeks to improve the efficiency and effectiveness of the regulatory process surrounding the siting of hydrokinetic power projects in New York State, with special emphasis on the transition from pilot to early commercial stages. The first step in this effort is to generate two background documents. Together, these two documents shall serve as the basis of discussion at an invitation-only expert workshop:

1. **A Review of Regulatory and Policy Requirements for Hydrokinetic Power Projects in New York State**; undertaken by Pace Energy and Climate Center, Pace Law School; provides an examination of New York State and federal policies.
2. **Marine and Hydrokinetic Technology - Background and Perspective for New York State,** undertaken by the Ocean Renewable Energy Coalition (OREC) and Verdant Power, represents a hydrokinetic power technology primer that provides context for the Marine and Hydrokinetic (MHK) industry and a state of the technology and environmental analysis, with a specific case study of the Verdant Power RITE Project environmental and regulatory history in New York since 2002.

The purpose of both documents is to provide workshop participants with the necessary background to be current with the issues and current state of the MHK industry in order to maximize planned participation in panel discussions and breakout sessions during the one-day workshop event. The discussions will focus on providing environmental policy direction for the MHK industry in New York State in the areas of:

- Encouraging Research and Development of Monitoring Tools
- Facilitating Data Networking, Exchange and Access
- Evolving Adaptive Management Policies
- Understanding the Nexus of New York State Energy and Environmental Policy

KEY WORDS

Environmental Effects of Kinetic Hydropower
Environmental Monitoring
Hydrokinetic
KHPS Environmental Assessment
Kinetic Hydropower
Kinetic Hydropower System (KHPS)
Marine and Hydrokinetic (MHK) industry
Ocean Renewable Energy Coalition (OREC)
Roosevelt Island Tidal Energy (RITE) Project
Tidal Energy
Verdant Power

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1. STATE OF THE MARINE AND HYDROKINETIC INDUSTRY

1.1 - Marine and Hydrokinetic Industry – What is it?

The Marine and Hydrokinetic (MHK) industry is one of the fastest growing sectors of renewable energy and is set to make a major contribution to carbon-free energy generation.[1]

Hydrokinetic stream energy extraction is derived from the kinetic energy of moving water flows, analogous to the way a wind turbine operates in air. A tidal or river stream energy converter extracts and converts the mechanical energy in the current into a transmittable energy form. A variety of conversion devices is currently being proposed or is under active development, but all are premised on the concept of renewable energy production from water currents without the need for dams or impoundments.

While various water current resources (river, tidal, canal) are included in the evolving MHK industry, tidal power has the advantage of a deterministic and precise energy production forecast, governed by astronomy. In addition, the predictable slack water facilitates deployment and maintenance. River power systems, while offering slightly higher capacity factors due to more regular flows, also face additional challenges due to siting in navigational waters with swift currents without known slack periods. In conjunction with technology development, the MHK industry has also supported a significant scientific research and environmental monitoring sub-industry to ensure the compatibility of the devices in operation.

The MHK industry is relatively new, evolving initially 10-15 years ago in the UK where the need for non carbon-based renewable energy and economic stimulus, combined with an abundant presence of developable tidal resources, drove a groundbreaking MHK roadmapping process for developing technology and monitoring environmental effects. The UK has also supported the development of the European Marine Energy Centre (EMEC) – an international test center located in the Orkney Islands and established to assist MHK technology developers in evaluating the performance of their machines (energy and environmental). Similarly, Canada has also embarked on a roadmaping exercise and established the Fundy Ocean Research Center for Energy (FORCE) as Canada's leading research centre for tidal energy, located in the Bay of Fundy, Nova Scotia.[2]

In the U.S., the MHK industry has also developed over the last ten years. Verdant Power has been active since 2002 at its Roosevelt Island Tidal Energy (RITE) Project, located in the East River in New York City. As further discussed in the Appendix C to this report, the RITE Project is a three-phase effort through which Verdant Power seeks to develop up to one megawatt (MW) of tidal power from the currents of the East River utilizing its proprietary Kinetic Hydropower System (KHPS). With the founding of the Ocean Renewable Energy Coalition (OREC) in 2005, the U.S. industry has gained momentum (Please see Appendix B-1 for additional MHK

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[1] *Assessment of Energy Production Potential from Tidal Streams in the United States - Final Project Report;* June 29, 2011; Georgia Tech Research Corporation

[2] EMEC: www.emec.org.uk and FORCE: www.fundyforce.ca

resources). Since 2008, the U.S. Government, through the U.S. Department of Energy (DOE) Wind and Water Power Program, has invested more than $50 million in the MHK sector.[3] The focus has been on two separate and distinct programs – Technology Development and Market Acceleration – with a goal to foster a commercial market for MHK energy devices in the near term. The DOE Marine and Hydrokinetic Factsheet is appended to this report as Appendix A.

In the U.S., tidal resource assessment potential was analyzed in a June 2011 study commissioned by the DOE, *Assessment of Energy Production Potential from Tidal Streams in the United States.* This report estimated the U.S. potential at 50.8 gigawatts (GW), representing 2,400 MW on the east coast and 48.4 GW on the west coast and Alaska and Hawaii.

A river hydrokinetic resource assessment is also currently underway by the Electric Power Research Institute (EPRI) under a separate DOE grant and results for the major U.S. waterways should be available by May 2012. Estimates from prior studies of the hydrokinetic potential on main-stem rivers in the U.S. have exceeded 10,000 megawatts (MW) and yielded an overall estimate of 12,500 MW. For purposes of this New York State workshop, we are focused on technologies, environmental effects and policy for the development of the potential of river and tidal resources, omitting wave. Based on the studies above, the estimated State resource tidal resource potential was estimated at 280 MW. Independent examinations by Verdant Power and others indicate this tidal potential could be somewhat greater. For river hydrokinetic potential, the estimated resource could be in the range of ~300 MW within New York State.

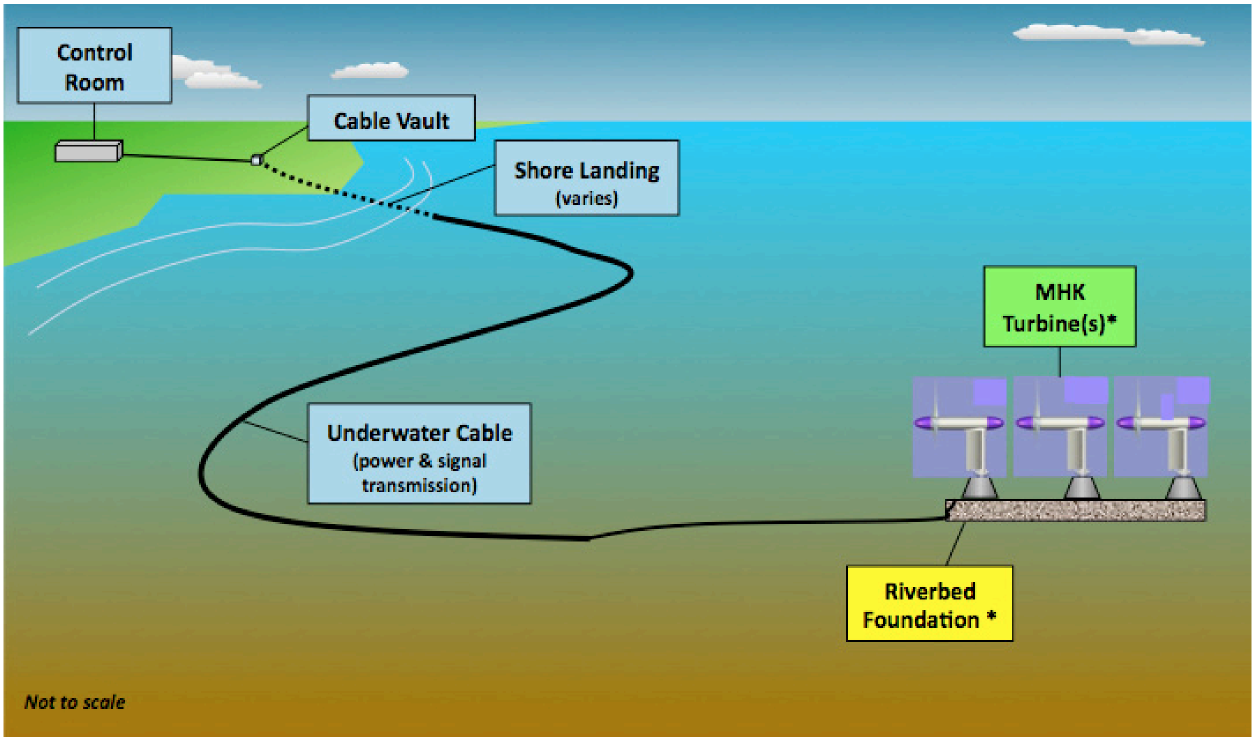
1.2 - MHK Project Components

In the rapidly developing MHK industry, there are three generic components that are commonly used to describe projects:

- The MHK technology (turbine), which has significant variability
- The riverbed mounting system (or foundation), again with variability; and
- The cables and land-based electrical infrastructure, which resemble all generation technologies.

How these components are combined into a "project" will depend on the purpose and maturity of the technology/project (i.e., trial/test, demonstration, pilot commercial or commercial) and the scale of the project, not only in installed capacity but in number of devices in the array or field. A generic representation of an MHK "project" is shown in below, followed by a discussion of the constituent components.

[3] This does not include a 2012 DOE budget announced in December of an additional appropriations package that includes $34 million for DOE's Water Power Marine and Hydrokinetic R&D program.



Generic MHK Project Layout

****Depiction shows Verdant Power's KHPS technology on a triframe foundation. As discussed, this configuration varies by project/technology.***

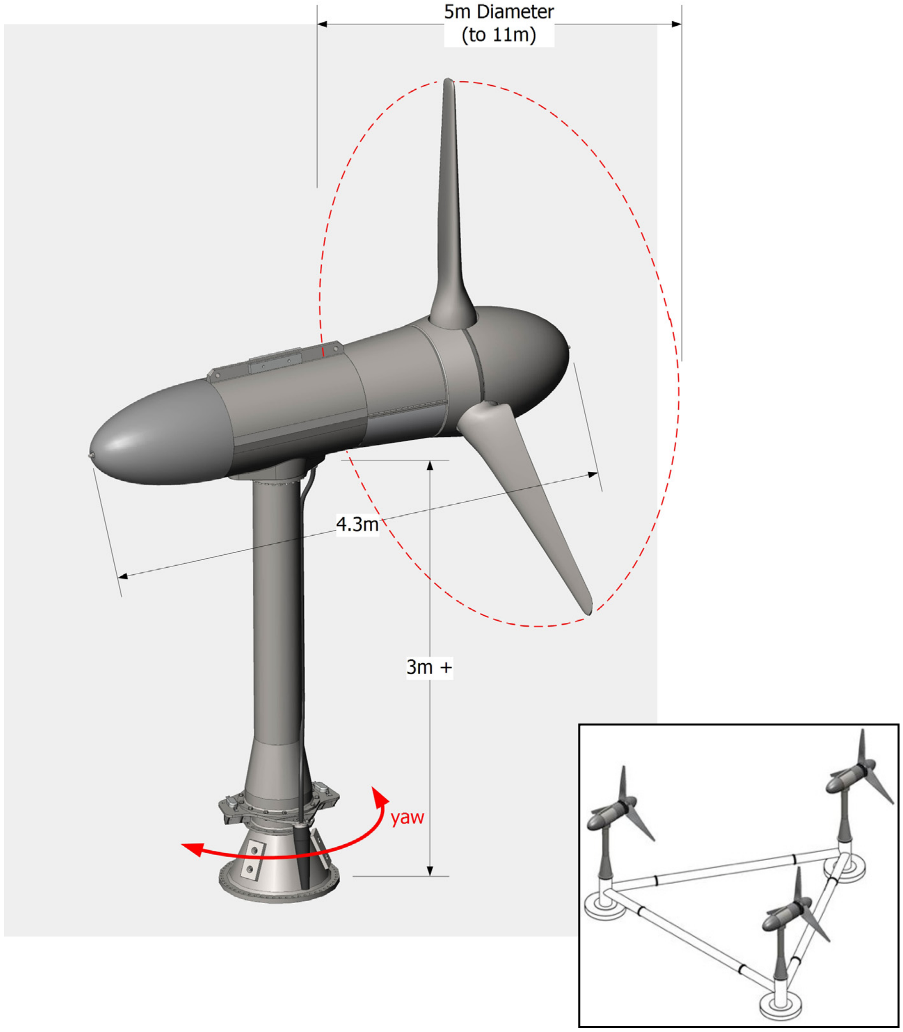
The MHK Technology

The MHK technology (turbine) will vary as devices continue to advance, with over 250 types in some stage of Technical Readiness Level (TRL).[4] The DOE Wind and Water Power Program defines and categorizes the technologies as follows:

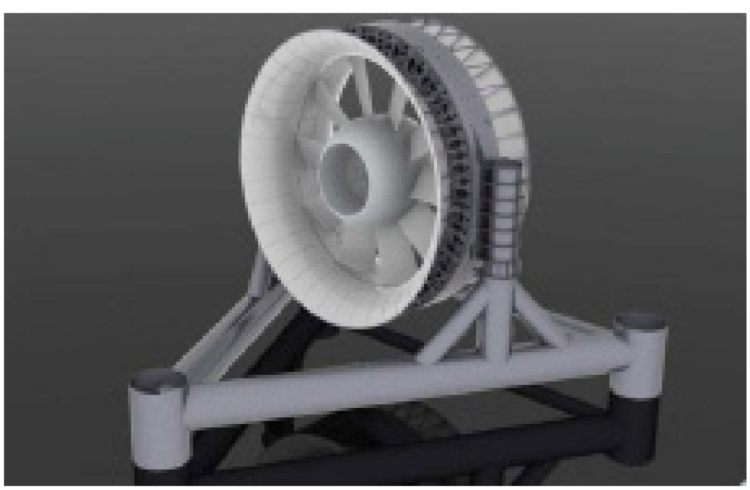
Axial Flow Turbines

Axial flow turbines typically have two or three blades mounted on a horizontal shaft to form a rotor. The kinetic energy of the water current creates lift on the blades causing the rotor to turn, driving a mechanical generator. These turbines must be oriented in the direction of flow. There are shrouded and open rotor models. The Verdant Power Kinetic Hydropower System (KHPS) turbine is an example of an open rotor axial flow design, as is the Marine Current Turbines (MCT) and Atlantis designs. The Hydro Green and Open Hydro designs are examples of shrouded axial flow turbines (See Appendix B-2 for photos).

[4] A commonly adopted definition of technology readiness level (TRL) is used in the industry; where TRL 1-3 is proof of concept; TRL 4-6 is lab and scale deployment; and TRL 7-9 is full scale; pre-commercial deployment.

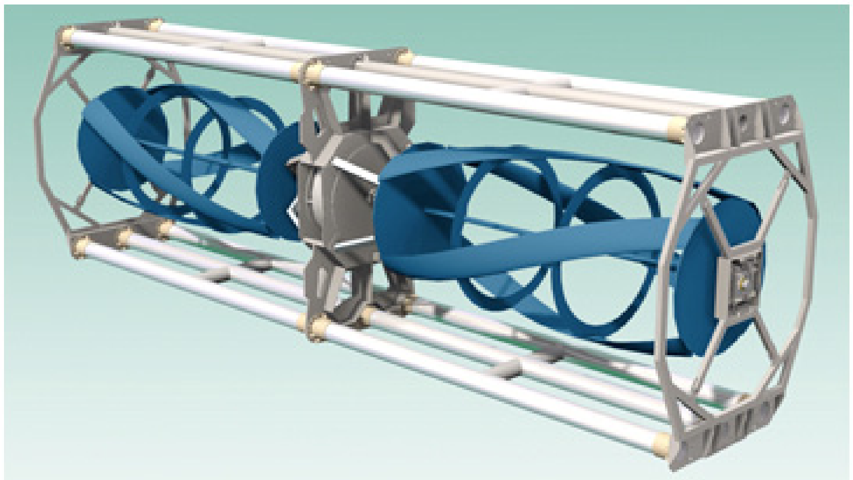


Verdant Power KHPS Axial Flow Turbine (Gen5) – Inset shows example of triframe foundation supporting three turbines (footing a construed concept to protect intellectual property rights)



Cross Flow Turbines

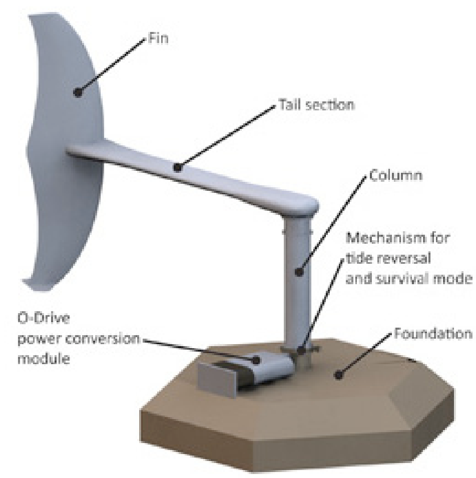
Cross flow turbines typically have a rotor formed by mounting two or more blades substantially parallel to a shaft that is typically vertical or horizontal. Horizontal cross flow rotors can capture kinetic energy from flows in two directions (e.g., flood and ebb) without an orientation change, while a vertical axis rotor can be omni-directional for river conditions. The ORPC turbine is an example (See Appendix B-2 for others).



Ocean Renewable Power Company (ORPC) Turbine Generator Unit (TGU)

Reciprocating Devices

This type of MHK technology uses the flow of water to produce the lift or drag of an oscillating part transverse to the flow direction. This behavior can be induced by a vortex, the Magnus effect, or by flow flutter. An example of a reciprocating device is the Oscillating Hydrofoil, which is similar to an airplane wing, though in water. Yaw control systems adjust their angle relative to the water stream, creating lift and drag forces that cause device oscillation. Mechanical energy from this oscillation feeds into a power conversion system. The bioSTREAM™ technology (BioPower Systems - Australia) is an example and is shown below.

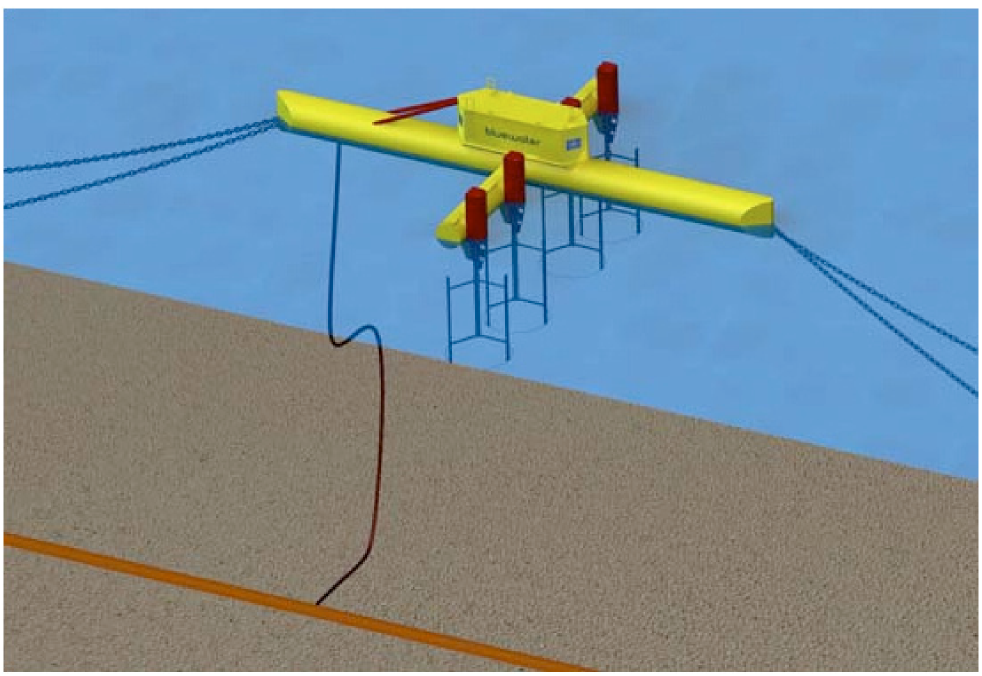


BioPower Systems bioSTREAM Technology
(Reciprocating Hydrokinetic Device)

Regardless of the design, devices will need to be robust and water sealed, protecting electric energy conversion systems (generators and drivetrains) from water intrusion and include protective coatings such as biocide paint or a low-friction coating to treat the surface of the device and protect it from biological fouling.

Riverbed Mounting System
The riverbed mounting system will vary significantly among devices and locations, and could include:

- Installed drilled surface-penetrating or underwater monopiles. Developers may propose to install either single (Verdant Power – RITE demonstration) or multiple (Free Flow Power) turbines on each monopile.
- Concrete or gravity base systems set on bottom surface. Gravity based systems can support single turbines (Open Hydro) or multiple devices (Verdant Power – RITE pilot).
- Floating mooring systems that allow devices to be surface-mounted with guy wires and floating platforms (based on oil and gas tanker mooring systems). An example of a mooring concept (Bluewater Bluetec – Netherlands) is shown below (see http://www.bluewater.com/bluetec for further information).



Bluewater Bluetec Floating Hydrokinetic Mooring System

Regardless of the design, all riverbed mounts must be economically and accurately deployed and retrieved, as well as being stable enough for long-term O&M activities in fast water environments. As can be seen, due to the variability of foundation concepts (size, function, location of multiple foundations in a particular project array), the level of effort for review of designs and associated environmental compatibility is significant. However, commonalities among assessments of habitat disruption can likely be made within classes of foundation adaptations, particularly since all of these foundation systems are similar to civil structures already placed (and permitted) in the marine environment, including bridge piles and piers;

floating tethers and buoy systems; and in-water gravity-based structures for moorings and towers.

Cables, Land-Based Facilities and Interconnection

Equipment and facilities for MHK projects include shoreline cable landings and interconnections, including a small shore-based Control Room (CR). These are site-specific and take into consideration the size of the project and the shoreline characteristics. The cables from the individual turbines are low-voltage and likely are grouped together and brought to shore into common landing vaults. Underwater cabling can be achieved with alternate configurations such as weighting or trenching at the shoreline. From the CR this allows a standard transformer/substation interconnect to be made to the electrical system. This entire land-based infrastructure is similar to any electric generating facility. An example of an MHK project control room is shown in Appendix C (RITE Project).

1.3 - MHK Project Development

As discussed above, an MHK "project" can vary widely in terms of technology, foundations and interconnection components. The DOE's Marine and Hydrokinetic Technology Database serves as a key resource for providing up-to-date information on MHK projects and associated technologies, both in the U.S. and around the world. The database represents wave, tidal, ocean current, and ocean thermal energy, and contains information on the various technologies, companies active in the field, and project development. Depending on the needs of the user, the database can present a snapshot of projects in a given region, assess the progress of a certain technology type, or provide a comprehensive view of the entire MHK industry.[5]

The DOE database contains entries for over 250 different technologies and over 465 projects that are active worldwide. Please see Appendix B-2 for additional information. Projects are listed according to their status and timeframe for execution:

- Phase 0 - Never Developed (Permit Surrendered or Unknown status)
- Phase 1 - Siting/Planning - one to three years
- Phase 2 - Site Development - two to four years
- Phase 3 - Device Testing/Commissioning [Pilot] - varies with technology status - one to ten years
- Phase 4 - Deployed [Grid Connected] - varies with project - one to ten years

The majority of the projects are in the 0-2 category, with only a handful advancing to Phases 3 or 4 at this time. Appendix B to this report provides a summary of some of those projects. Verdant Power's RITE Project in the East River in New York City, (the subject of the Case Study in Appendix C) is one project that has achieved the Phase 3/4 status. It should be noted that moving both a technology and a project through these phases is a multi-year commitment.

The various MHK technologies and device developers are on varying paths of technology readiness[6] and project development, and as such do complicate the comprehensive development

[5] *www1.eere.energy.gov/windandhydro/hydrokinetic*

[6] A commonly adopted definition of technology readiness level (TRL) is used in the industry; where TRL 1-3 is proof of concept; TRL 4-6 is lab and scale deployment; and TRL 7-9 is full scale; pre-commercial deployment.

of environmental effects research and review. The distinction and proof of the environmental performance of each technology falls to the technology developer to present the case for environmental compliance and compatibility. It remains the responsibility of the regulators to view each project and technology concept as presented in the context of discharging their responsibilities under law.

Demonstrations, Pilots and Field Arrays

An important distinction as MHK projects develop is the concept of multiple machine placing. While the industry has sited several dozen types of devices in natural waters worldwide for testing, these installations have been limited to one or two, and in the case of Verdant Power, six operating MHK turbines at a single location. These demonstrations (at TRLs 5/6 or 7/8) are now leading to pre-commercial or commercial pilots that still involve a smaller number of machines – for example, the RITE pilot is 30 turbines for one MW. A common definition was adopted for review by the industry[7]:

> *The significance and uncertainty associated with a particular stressor/receptor interaction may vary with the scale of development. For example, the acoustic effects of a single pilot turbine may be insignificant in the context of existing ambient noise sources but could be significant for a commercial array consisting of a hundred turbines. To account for this, [discussions during the workshop] differentiated between pilot-scale deployments (to indicate high-priority areas in the near-term) and commercial-scale deployments (to indicate high-priority areas in the long-term).*
>
> *Pilot projects were considered to have the following characteristics:*
>
> - *Single devices or small device arrays;*
> - *Deployment durations of less than a decade;*
> - *Provisions for project shutdown and early removal if unacceptably large environmental impacts are observed;*
> - *Power extracted by a pilot project is much less than natural tidal dissipation in the project area;*
> - *The rotor swept area (sum of the cross-sectional area swept by all turbines) for a pilot project is much less than the cross-sectional area of the channel in which it is deployed; and*
> - *The primary goal of pilot projects is research and development (i.e., revenues generated by electricity sales are relatively incidental compared to the implementation cost).*
>
> *This working definition is qualitatively similar to that adopted by the Federal Energy Regulatory Commission (FERC) for pilot licensing (FERC 2008), but does not adhere to the same quantitative standards (e.g., FERC defines pilot projects as having a rated capacity of less than 5 MW).*

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[7] *Environmental Effects of Tidal Energy Development: A Scientific Workshop* [http://depts.washington.edu/nnmrec/workshop/docs.html]

For the purposes of breakout group discussions, commercial projects were considered to have the following characteristics:

- *Large device arrays (e.g., > 100 devices);*
- *Service lives of 20-30 years and licensing periods of up to 50 years;*
- *Power extracted by a commercial project may be on the same order as natural tidal dissipation in the project area;*
- *The rotor-swept area for a commercial project may be on the same order as the cross-sectional area of the channel in which it is deployed; and*
- *The primary goal of commercial projects is utility-scale power generation that is cost-competitive with other forms of electricity.*

As the tidal energy industry evolves worldwide, the scale of pilot projects will likely increase, and the line between late-stage pilot projects and early-stage commercial projects may be blurred.

Environmental Review of MHK Projects

As discussed in Section 2 of this report, the evolution of the environmental review of MHK technology revolves around a comprehensive assessment of the components as they are assembled into a project. The history of consultation at the RITE Project has addressed many of the issues and concerns related to the Verdant KHPS and the RITE site. A full discussion of environmental effects for the Verdant KHPS is included in Appendix C, as an example of the level of environmental study and review of a specific MHK technology. However, the following are some questions that are relevant to MHK development in general.

Can MHK technologies cause damage to fish and other aquatic animals from water pressure changes, cavitation, shear stress, or turbulence?

The answer to this question will vary widely and specifically with the type of technology installed. The mechanisms mentioned are largely due to entrainment, entrapment and entanglement with devices that have moorings, ducts or shrouds, or strikes with respect to open-rotor designs. The body of evolving research on this issue is a significant undertaking and the reader is invited to explore the literature on specific technology design to ascertain the relevance of data.

Some MHK turbines by design do not have penstocks, ducts, shrouds, intakes or screens, and as such the damage/injury to fish by water pressure change, cavitation, and shear stress or turbulence mechanisms is generally understood to be not applicable. Open-rotor and shrouded machines have also been studied for strike interaction with variable results, again specifically tied to the technology and the species in-situ.

Can MHK technologies cause changes in water temperature and thermal stratification, or changes in dissolved gases or chemistry?

Given the extremely energetic and dynamic conditions of high velocity water necessary for the technology to produce electricity, thermal or chemistry issues are unlikely at a small project scale. While mixing phenomenon is perhaps important at a large project scale, the literature points to concerns only when significantly larger arrays are being considered. Any effect from rotating or stationary turbine rotors would be to increase mixing and reduce stratification, but will also be slight relative to this already highly turbulent and well-mixed resource.

What about issues related toxicity of paints and antifouling coatings?

Marine industry paints and antifouling coatings have been used for years in various applications, and undergo constant improvement process for environmental compatibility. As noted in the literature, the type and toxicity will vary with the coating technology utilized, and this will be technology-specific. At this time, non-toxic coating systems are available and used by the MHK technologies, therefore it is generally agreed that, while it is an issue to review, coatings on MHK machines do not pose any toxicity concerns.

Is there an issue with other pollutants entering the water?

As with any on-water activity, discharge from vessels servicing an MHK project is always a possibility during the installation and maintenance activities, but the risk is the same as any with any vessel and precautions are in effect and spill incidents are regulated. For the MHK machines themselves, turbine lubricants and their containment systems will vary widely with the technology installed in terms of volume (generally small amounts), type (usually food grade or water compatible) and risk (i.e., containment, alarming).

Are there potential issues with respect to generation of electromagnetic fields (EMF)?

As discussed in the literature, EMF considerations will vary widely with the technology installed and the length, voltage and design of the underwater cables, however it is still likely to be less than existing sources of underwater cables for other power and telecommunications services. At the demonstration and small pilot scales, it is generally agreed that MHK technology does not pose any EMF concerns, although that likely will be receptor site specific.

1.4 - United States MHK Roadmap

In November 2011, the Ocean Renewable Energy Coalition (OREC) unveiled the first U.S. Marine and Hydrokinetic (MHK) Technology Roadmap. The roadmap describes the issues, challenges and opportunities facing the MHK industry and outlines a clear and logical path to its commercialization. This document – commissioned by the DOE and developed with industry, scientific peer review and regulator input – asserts that MHK technologies represent the potential to provide up to ten percent of U.S. electricity consumption. The U.S. Roadmap and Executive Summary are available online at: http://www.oceanrenewable.com/roadmap.

The U.S. MHK Roadmap spells out the steps necessary to achieve at least 15 GW of grid-connected MHK power by 2030 and to create up to 36,000 MHK-related direct jobs in the process. The roadmap emphasizes the need for coordinated efforts; continued funding for research, development and deployment activities; and support for an environmental study program that would help place vital data into the public domain.

This roadmap and continued federal support will help protect these investments and lead to energy independence, a cleaner environment and the potential to export clean energy technology and capture a piece of this global market, which is estimated at over $600 billion USD.

The U.S. MHK Roadmap outlines the following key technology and environmental areas:

1. Technical Research and Development
   - Perform fundamental and applied research on MHK technologies.
2. Policy Issues
   - Develop a policy framework that supports a stable market and informs and educates policymakers.
3. Siting and Permitting
   - Assess high potential marine resources and develop siting and permitting guidelines for development.
4. Environmental Research
   - Perform in situ studies of effects and benefits of MHK energy generation technologies and establish methods to avoid, minimize and mitigate.
5. Market Development
   - Develop a market expansion needs assessment including jobs, ports, ships, materials, community education, standards and approaches for meeting them.
6. Economic and Financial Issues
   - Analyze support mechanisms, technology pathways, performance, cost and deployment and develop approaches to address any barriers.
7. Grid Integration
   - Support utility integration studies that assess variability, capacity value, interconnection and approaches to overcoming these barriers including the benefits of predictable MHK generation.
8. Education and Workforce Training
   - Develop the science, engineering and technician educational programs needed to support the MHK industry.

1.5 - MHK Industry Economic and Growth Perspective

As outlined in the OREC MHK Roadmap, the MHK industry has significant potential for job creation in the manufacturing and marine services sectors. Using the range of 2.1 to 2.4 job years per MW, the roadmap estimates that, based on the goal of 15 GW installed capacity by 2030, up to 36,000 direct and indirect jobs could be created across the U.S. for fabrication, installation, operations and maintenance of MHK devices.

New York State Commercial Market / Importance to New York State

The MHK energy potential in New York State is estimated to be on the order of 500-800 MW. In addition to the East River (East and West Channels), other large New York State MHK resources include areas within Long Island Sound, the St. Lawrence River and the Niagara River. Implemented in these and other local sites, MHK devices could provide clean renewable energy that would help New York meet its greenhouse gas (GHG) reduction goals, including Renewable Portfolio Standard goals. These projects would also generate locally-sourced energy that would help the state reduce its electricity imports, which made up approximately 85 percent of energy delivered in the state in 2005.

Verdant Power RITE Project (East River – New York City)

The potential impact of Verdant Power's RITE Project (see Case Study in Appendix C) on New York City was highlighted in a report entitled "New York City's Transformation to a Green Economy," which listed the effort as one of 30 initiatives New York City envisions playing a key role in transforming its economy. Through the RITE Project and previous NYSERDA support, Verdant Power has worked to make New York (City and State) a center for this emerging industry and its manufacturing/installation potential in the U.S. and internationally.

As required in its commercial license application for the RITE Project submitted to the Federal Energy Regulatory Commission (FERC), Verdant Power estimated the RITE Project's benefits to the local economy in terms of job creation and business opportunities in the construction, manufacturing and utilities industries. Verdant Power utilized the National Renewable Energy Laboratory's *Job and Economic Development Impact (JEDI)* model, developed in beta form for hydrokinetics, to estimate the potential economic development benefits, including job creation that would result from the development of the proposed 1 MW pilot. Through this exercise, Verdant Power found that the 1 MW project could produce up to 136 construction jobs and 12 permanent jobs, with an overall economic output, direct, indirect and services of over $27 million.

In addition to energy generation, the commercialization of Verdant Power's KHPS would also benefit the New York State economy, making the State the manufacturing center for a new renewable energy technology with international export potential. Through a project sponsored by NYSERDA, Verdant Power identified specific manufacturing sites for future commercial installations that would result from this project. The supply chain goods and services for just the RITE Project has extended to not only include New York State manufacturing and assembly, but vendors in at least seven different non-coastal states and across all job sectors including environmental consultants, engineering design, academia, national labs as well as the manufacturing and testing sectors.

2. EVOLUTION OF ENVIRONMENTAL EFFECT RESEARCH & EVALUATION

In 2000, as the first MHK projects were being proposed worldwide, scientists, regulators and developers struggled to develop an evaluation framework that protected the environment while still allowing the MHK industry to grow and fill information gaps where environmental effects were not well understood. The evolution of environmental concerns is summarized below with a significant reference and reading list for further details. This is intended to characterize the extent of environmental effects considerations that are relevant to the emerging industry in the U.S. and particularly where environmental operational monitoring will need to play a role as the industry advances.

2.1 - Early (2005-07) U.S. Workshops and Proceedings

In the U.S., several initial workshops[8] were conducted by FERC, EPRI and others, including an ad hoc group called the Environmental Policy Board, which met in January and May 2007, to initiate dialogue about potential environmental effects of MHK projects and how regulators could move projects forward while studying their effects on the environment. These initial workshops identified that the understanding of environmental effects would require both an operative framework for environmental research as well as a regulatory pathway that allowed small-scale technology demonstrations and "Pilots" to be allowed in the water with concurrent environmental monitoring.

2.2 - FERC April 2007 Hydrokinetic Whitepaper[9]

These discussions formed the basis for an action by the Federal Energy Regulatory Commission (FERC) to define a Hydrokinetic Pilot Project framework. In its April 2007 whitepaper, FERC gave direction that Hydrokinetic Pilot Projects should meet the following criteria:

- Small;
- Short term;
- Not located in sensitive areas based on the Commission's review of the record;
- Removable and able to be shut down on short notice;
- Removed, with the site restored, before the end of the license term (unless a new license is granted); and
- Initiated by a draft application in a form sufficient to support environmental analysis.

2.3 - December 2009 DOE Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies

The DOE commissioned a report in December 2009 that outlined (1) the potential environmental impacts of marine and hydrokinetic energy technologies, (2) options to prevent adverse environmental impacts, (3) the potential role of monitoring and adaptive management, and (4) the necessary components of an adaptive management program. The report[10] stated:

> *Some aspects of the environmental impacts [from MHK projects] will be unique to specific technologies or the environmental setting, requiring operational monitoring to*

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[8] U.S. Workshops and Proceedings: Hydrokinetic and Wave Energy Technologies Technical and Environmental Issues Workshop. 2007. URL: http://hydropower.inl.gov/hydrokinetic_wave

Cada, G., J. Ahlgrimm, M. Bahleda, T. Bigford, S. Damiani-Stavrakas, D. Hall, R. Moursund, and M. Sale. 2007. Potential impacts of hydrokinetic and wave energy conversion technologies on aquatic environments. Fisheries 32(4): 174-181.

Coutant, C.C. and G.F. Cada. 2005. What's the future of instream hydro? Hydro Review XXIV(6):42-49.

[9] Federal Energy Regulatory Commission (FERC). April 2007. Hydrokinetic Licensing Procedures. URL: http://www.ferc.gov/industries/hydropower/gen-info/licensing/hydrokinetics.asp

[10] U.S. Department of Energy, Wind and Waterpower Program. December 2009. Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies. URL: www1.eere.energy.gov/water/pdfs/doe_eisa_633b.pdf (Page i).

[10] Ibid. iv.

[10] Ibid. ii.

determine the extent of the effects. Because the environmental effects of technologies are a function of both project design and site conditions, small projects sited in non-sensitive areas may not require extensive studies. On the other hand, large projects, especially those located in environmentally sensitive areas or in the presence of endangered species, may be more likely to warrant substantial investigations. It should be emphasized that the potential significance of many of the environmental issues cannot yet be determined due to a lack of experience with operating projects. Also, the severity of these impacts could be increased by the cumulative effects of multiple units within a project, multiple projects, or energy projects coupled with other stressors.

Predictive environmental effects discussed in this high level review included:

- Alteration of current and wave strengths and directions;
- Alteration of substrates and sediment transport and deposition;
- Alteration of habitats for benthic organisms;
- Noise during construction and operation;
- Generation of electromagnetic fields (EMF);
- Toxicity of paints, lubricants, and antifouling coatings;
- Interference with animal movements and migrations, including entanglement; and
- Strike by rotor blades or other moving parts.

This report has guided the development of a DOE environmental program to prioritize and support environmental effects research, as discussed in section 2.8. Another key finding was the need to concurrently develop monitoring plans in conjunction with advancing in-water full scale device deployments so that the environmental research could be validated with operating MHK devices.

2.4 - March 2010 Environmental Effects of Tidal Energy Development: Proceedings of a Scientific Workshop[11]

The workshop was conducted in February 2009 by the University of Washington and attended by academia, research groups, regulatory agencies, and the MHK industry. Potential environmental effects were examined in focus groups grouped in the same categories that were identified in the 2009 DOE report.

The workshop went on to reference potential effects in terms of a specific site's conditions and its physical and biological environment in terms of Stressors and Receptors, with the workshop participants examining each in a two-day session.

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[11] NOAA. Environmental Effects of Tidal Energy Development: Proceedings of a Scientific Workshop. March 2010. URL: http://spo.nmfs.noaa.gov/tm/116.pdf. Page 19.

[11] Ibid. 18.

Stressors are defined as those factors that may occur as tidal energy systems are installed, operated, or decommissioned, including:

- Presence of devices: static effects;
- Presence of devices: dynamic effects;
- Chemical effects;
- Acoustic effects;
- Electromagnetic effects;
- Energy removal; and
- Cumulative effects.

Receptors were defined as those elements of the marine environment that may be affected by stressors including:

- Physical environment: near-field;
- Physical environment: far-field;
- Habitat;
- Invertebrates;
- Migratory fish;
- Resident fish;
- Marine mammals;
- Seabirds; and
- Ecosystem interactions.

Additionally, the workshop proceedings made a distinction between demonstration- and pilot-scale effects and commercial-scale effects, recognizing that environmental effects can come in the forms of installation effects, operational effects, decommissioning effects, accidents and project scale.

> *Development of tidal energy involves technology testing, site characterization, device installation, operation and maintenance, and decommissioning. Many installation and decommissioning effects have close analogues to existing industries (e.g., offshore wind) and are short-term. Consequently, this report places an emphasis on operational effects experienced over the long term and installation/decommissioning effects unique to tidal energy.*

The workshop came to two overarching conclusions:

- The next step to reducing critical uncertainties is careful monitoring of pilot-scale device deployments;
- Research efforts must be prioritized and leveraged in order to effectively direct limited research dollars and resolve key uncertainties in a timely manner. [12]

[12] Ibid. 18.
[12] Ibid. 130.
[12] Ibid. 130.

2.5 - International Energy Agency (IEA) Annex IV

The Annex IV Project is focused on gaining a better understanding of the potential environmental effects of marine renewable energy devices from a worldwide perspective. Sharing environmental data will help increase understanding of effects, minimize the potential for redundancy of efforts, and increase the efficiency of the permitting and consenting processes. This effort is an international effort initiated by the International Energy Agency's Ocean Energy Systems Implementing Agreement (OES-IA) to identify research or data collection efforts that are being conducted around the world, along with available results, and produce a public database to house this information. The activities are ongoing but the database will house information on:

- Key Environmental issues: brief description on the most important environmental issues raised by the project (e.g., Sensitive species/habitats/areas that were of particular concern and/or received special protection) and how they were addressed.
- Project self reporting on Monitoring program descriptions; design and methods, results and status as to whether the environmental work is planned, underway, or completed.

The MHK Environmental Impacts Knowledge Management System (KMS) (dubbed "Tethys" after the mythical Greek Titaness of the seas) supports the DOE's Wind and Water Power Program.

As industry, academia, and government seek to develop new renewable energy sources from moving water and offshore wind, potential environmental effects must be evaluated and measured to ensure that aquatic and avian animals, habitats and ecosystem functions are not adversely affected, nor that important coastal and ocean uses are displaced. This database – when populated – will form a unique repository for environmental data for the MHK industry. Verdant Power submitted information in April 2012 for the RITE project. Please see mhk.pnnl.gov for more details.

2.6 - Other U.S. MHK Related Environmental and Regulatory Streamlining Activities

November 2010 ARPA-E Proposed Categorical Exclusion B5.25

In November 2010 the Acting Chief Counsel of the Advanced Research Projects Agency - Energy (ARPA-E) submitted a memorandum in support of proposed categorical exclusion (CX) B5.25, "Small-scale renewable energy research and development and pilot projects in salt water and freshwater environments"[13].

The document proposed an exclusion of small-scale MHK pilot projects from the NEPA process as long as they were sited in non-sensitive environments and not permanent. This proposal for a categorical exclusion was supported by scientific and technical expert opinion, as well as the experiences of the DOE, other federal agencies, foreign governments, and private industry. The NEPA categorical exclusion for small-scale MHK pilot projects went into effect on November 11, 2011.

[13] ARPA-E. November 2010. Proposed Categorical Exclusion B5.25 Small-scale renewable energy research and development and pilot projects in salt water and freshwater. URL: http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/CXR-ARPAETechSupportMemo.pdf

U.S. Army Corps of Engineers Nationwide Permits (NWP)
On February 18, 2011, the U.S. Army Corps of Engineers (USACE) proposed a nationwide permit for small MHK projects of up to ten units. A nationwide permit (NWP) relieves developers of filing a site-specific application, and instead authorizes the activities covered by the permit if the project meets the eligibility requirements. A NWP 52 *Water-Based Renewable Energy Generation Pilot Projects* was implemented February 12, 2012.

Memorandum of Understanding (MOU)
As discussed, one of the challenges to streamlined permitting is the involvement of multiple federal, state and local agencies, which frequently do not coordinate. To improve cooperation, FERC has entered into separate MOUs with Oregon, Washington, California, Maine and Colorado. These MOUs define the roles of each party and commit them to work together for more expeditious licensing of MHK projects. On the federal side, FERC has also executed MOUs with the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and USACE to coordinate licensing.

2.7 - Ongoing U.S. Environmental Research
The evolution of understanding described above has stimulated a program of scientific study, in the U.S. and around the world. Moving forward, and in addition to project developer-based environmental modeling via regulatory processes, the DOE continues to sponsor various environmental research activities relevant to the MHK industry. Some recent awards include[14]:

- Dehlsen Associates, LLC (Carpinteria, CA) will first develop a bottom habitat survey methodology and siting study approach in accordance with all relevant regulatory agencies in the southeast Florida region; then they will determine the most suitable areas for mooring marine and hydrokinetic facilities based on the distribution of sensitive bottom habitats identified by existing and supplemental surveys. *DOE share: up to $600,000; Duration: up to one year.*
- Electric Power Research Institute (Palo Alto, CA) will perform a comprehensive assessment of existing U.S. in-stream hydrokinetic resources and the optimal achievable energy conversion rates which could be produced by future hydrokinetic turbine machines from those resources. *DOE share: up to $500,000; Duration: up to one year.*
- Electric Power Research Institute (Palo Alto, CA) will perform desktop and laboratory flume studies that will produce information needed to determine the potential for injury and mortality of fish that encounter hydrokinetic turbines of various designs installed in tidal and river environments. Behavioral patterns will also be investigated to assess the potential for disruptions in the upstream and downstream movements of fish. *DOE share: up to $600,000; Duration: up to one year.*
- Re Vision Consulting, LLC (Sacramento, CA) will develop life-cycle cost profiles for different site and wave, tidal, ocean current, and in-stream hydrokinetic technology combinations using baseline representative commercial project development data from specific sites. *DOE share: up to $500,000; Duration: up to one year.*

[14] U.S. Department of Energy Press Release; September 15, 2009

- Ocean Renewable Power Company (Portland, ME) will use a new combination of monitoring technologies to collect baseline data on pre-deployment patterns of marine mammal distribution in Cook Inlet, Alaska, with special emphasis on the endangered beluga whale. Monitoring during and after deployment will then occur to determine marine mammal interaction with the company's tidal turbine. *DOE share: up to $600,000; Duration: up to one year.*
- Harris Miller Miller & Hanson (Burlington, MA) will deploy two established tidal energy technologies near Martha's Vineyard and collect and analyze information related to sediment transport alteration and impacts on protected species. *DOE share: up to $600,000; Duration: up to one year.*
- Free Flow Power Corporation (Gloucester, MA) will design, implement, and test an electrically interconnected hydrokinetic turbine pylon installation to achieve maximum water-to-wire efficiency. Special emphasis will be placed on the design of a mooring system that maximizes efficiency of installation and maintenance. *DOE share: up to $750,000; Duration: up to two years.*
- Public Utility District #1 of Snohomish County (Everett, WA) will determine the types of aquatic species in Admiralty Inlet, Washington and will determine both baseline levels of background noise as well as the acoustic impacts that hydrokinetic turbines will have on these species. *DOE share: up to $600,000; Duration: up to one year.*
- Ocean Renewable Power Company (Portland, Maine) will build, install, operate, and monitor a commercial-scale array of five grid-connected TidGen™ Project devices on the sea floor in Cobscook Bay off Eastport, Maine in two phases over three years. The project will advance ORPC's cross-flow turbine tidal energy technology, producing a full-scale, grid-connected energy system and will gather critical technical and cost performance data for one of the most advanced tidal energy systems in the U.S. The completed project will comprise an array of interconnected TidGen™ hydrokinetic energy conversion devices, associated power electronics, and interconnection equipment into a system fully capable of commercial operation in moderate to high velocity tidal currents in water depths of up to 150 feet. The project will significantly advance the technical, operational and environmental goals of the tidal energy industry at large. *DOE Funding: $10,000,000. Total Project Value: $21,100,000.*
- Public Utility District No.1 of Snohomish County (Everett, Washington) will deploy, operate, monitor, and evaluate two 10-meter diameter Open-Centre Turbines, developed and manufactured by OpenHydro Group Ltd, in Admiralty Inlet of Puget Sound. The project is expected to generate 1 MW of electrical energy during periods of peak tidal currents with an average energy output of approximately 100 kilowatts (kW). This full-scale, grid-connected tidal turbine system will gather critical technical and cost performance data for one of the most advanced tidal turbine projects in the DOE *Funding: $10,000,000. Total Project Value: $20,100,000.*[15]

[15] DOE press release September 9, 2010

These studies and project deployments promote the understanding of the environmental effects of the evolving MHK industry to begin to answer some of the relevant stressor/receptor questions.

In April 2011, during a DOE-sponsored workshop on MHK instrumentation [Ref 14], participants concluded that such instrumentation systems would need further development to meet the needs of the MHK industry. Key lessons learned noted that:

1. Device developers lack the resources and capabilities to instrument pilot-scale deployments for performance, environmental, and ecological monitoring.
2. Standards are needed for both the collection and analysis of field data.
3. No comprehensive instrumentation system solution exists for MHK systems.
4. Standardized instrumentation systems and measurement methodologies are needed for MHK device deployment.
5. Communication between instrument and sensor manufacturers and the offshore wind and the MHK communities should be encouraged.

2.8 - Potential Environmental Effects – Summarizing the State of the Industry

Several summary points can be made from the body of developing environmental effects studies and workshops from the proceedings mentioned above:

- The distinction between demonstration/pilot and commercial project effects can be made, that allows for the streamlining of early stage projects in order to assess environmental effects begin to fill in gaps of understanding.
- Understandings of environmental effects of other marine activities are useful in defining effects from MHK projects.
- The operation of the MHK devices is needed in a controlled and monitored scenario to fully understand environmental effects.
- Monitoring plans will require scientific approaches, developed in a collaborative process, with an application of adaptive management.
- The results, efficacy and understandings culminating from the monitoring need to be transparent and inform the industry at large.
- Near field and far field effects require separate consideration, and a framework for longer-term studies.
- Technology and site specific effects need to be analyzed and supported, but there may be some possible transference of knowledge from one site to the next.
- The specific site conditions, size and duration of project, and energy conversion device specifics will ultimately need to be examined in detail as part of an environmental assessment at specific locations, using the understandings developed above.

3. REFERENCES AND MHK READING LIST

1. Colby, J., A., Adonizio, M. A.; Hydrodynamic Analysis of Kinetic Hydropower Arrays; Waterpower XVI, no. 204; July 2009
2. Coutant, Charles C, and Cada Glenn F.; *"What's the Future of Instream Hydro?';* Oak Ridge National Laboratory; Oak Ridge, TN. HydroReview, Volume 24, Number 6; October 2005
3. Environmental Effects of Tidal Energy Development A Scientific Workshop*;* April 2011 *(*http://depts.washington.edu/nnmrec/workshop/docs.html)
4. Marine Renewable Strategic Environmental Assessments:
   a. Bay of Fundy 2008: http://www.offshoreenergyresearch.ca/OEER/
   b. Scotland 2007 http://www.seaenergyscotland.co.uk/
5. U.S. Department of Energy, Wind and Waterpower Program; Hydrokinetic and Wave Energy Technologies Technical and Environmental Issues Workshop*;* 2006 (http://hydropower.inl.gov/hydrokinetic_wave)
6. U.S. Department of Energy, Wind and Waterpower Program; *Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies;* December 2009 (www1.eere.energy.gov/water/pdfs/doe_eisa_633b.pdf)
7. Verdant Power, LLC. *The RITE Project License Application* (P-12611-005); December 2010; (www.thereiteproject.com, and the FERC public docket at www.ferc.gov)
8. *Charting the Course: Canada's Marine Renewable Energy Technology Roadmap*; Ocean Renewable Energy Group (OREG); October 2011
9. *NYSERDA Roosevelt Island Tidal Energy (RITE) Environmental Assessment Project Final Report 11-04*; March 2011 (Available at http://www.theriteproject.com/Documents.html).
10. Ocean Renewable Energy Coalition (OREC); *U.S. Marine and Hydrokinetic Renewable Energy Roadmap*; October 2011.
11. *Ocean Energy Roadmap* (http://www.seai.ie/Renewables/Ocean_Energy_Roadmap.pdf)
12. *UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap* (http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf)
13. Georgia Tech Research Corporation; *Assessment of Energy Production Potential from Tidal Streams in the United States* (DOE Award Number: DE-FG36-08GO18174 Final Report); June 29, 2011
14. DOE, Energy Efficiency and Renewable Energy; Wind and Water Power Program. 1st Advanced Marine Renewable Energy Instrumentation Experts Workshop; April 5-7, 2011 www1.eere.energy.gov/water/pdfs/51584.pdf
15. *Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State*; Annals of the New York Academy of Sciences, 1244: 2–649. doi: 10.1111/j; November 2011 (Full report may be found at www.nyserda.ny.gov).

APPENDIX A - U.S. Department of Energy MHK Fact Sheet

APPENDIX B-1 - MHK Resources

OREC Corporate and Academic Members	Web site
Alden Research Laboratory, Inc.	www.aldenlab.com
Battery Ventures	www.battery.com
Beveridge & Diamond	www.bdlaw.com
Biosonics	www.biosonicsinc.com
Central Lincoln People's Utility District	www.clpud.org
Chadbourne & Park, LLP	www.chadbourne.com
Chevron Technology Ventures	www.chevron.com/ctv
Columbia Power Technologies	www.columbiapwr.com
Current to Current	www.currenttocurrent.com
Dresser Rand	www.dresserrand.com
HDR/DTA	www.devinetarbell.com
Ecology & Environment, Inc.	www.ene.com
Florida Atlantic University	snmrec.fau.edu
Kleinschmidt	www.kleinschmidtusa.com
Lockheed Martin Corporation	www.lockheedmartin.com/us.html
Long Island Power Authority	www.lipower.org
University of Michigan Marine Renewable Energy Laboratory	name.engin.umich.edu/fac/michaelb
Millbank Tweed Hadley & McCloy, LLP	www.milbank.com
Natural Currents	www.naturalcurrents.com
New England Marine Renewable Energy Center (MREC)	www.mrec.umassd.edu
Ocean Power Technologies	www.oceanpowertechnologies.com
Open Hydro (Ireland)	www.openhydro.com
Ocean Renewable Power Company	www.orpc.co
Ocean Wave Energy Company	www.owec.com
Oregon State University	eecs.oregonstate.edu
Oregon Wave Energy Trust	www.oregonwave.org
Pacific Gas & Electric Company	www.pge.com
Pelamis Wave Power Limited (Scotland)	www.pelamiswave.com
Puget Sound Energy	www.pse.com
Pierce Atwood, LLP	www.pierceatwood.com
Reluminati	www.reluminati.com
RenewableEnergyAccess.com	www.renewableenergyaccess.com
Resolute Marine Energy, Inc.	www.resolute-marine-energy.com
SAIC	www.saic.com
Sea Mammal Research Unit Ltd.	www.smru.st-andrews.ac.uk
Scottish Development International	www.sdi.co.uk
Simmons & Company International	www.simmonsco-intl.com
SMI, Inc.	www.strategicmi.com
SML Consulting	www.smlconsulting.net

OREC Corporate and Academic Members	Web site
Snohomish Public Utility District	www.snopud.com
Sound & Sea Technology, Inc.	www.soundandsea.com
Southern Company	www.southernco.com
The Stella Group	www.thestellagroupltd.com
Stoel Rives, LLP	www.stoel.com
Tacoma Power	www.tacomapower.com
Teledyne	www.teledyne.com
TRC Companies	www.trcsolutions.com
Turner Hunt Ocean Renewables, LLC	www.turnerhuntocean.com
University of Massachusetts-Dartmouth	www.atmc.umassd.edu
University of Washington	http://www.washington.edu/research/energy/topics/generation/tidal/hydrokinetics
Van Ness Feldman	www.vnf.com
Verdant Power	www.verdantpower.com
Wavebob, Ltd.	www.wavebob.com
WaveStar Energy (Denmark)	www.wavestarenergy.com
Yakutat Power	http://www.yakutatak.govoffice2.com/index.asp?Type=B_BASIC&SEC={E1E3A709-23A3-428A-9B46-45507A3091D8}
Northwest Public Power Association	www.nwppa.org
RenewableEnergyWorld.com	www.renewableenergyaccess.com
Scottish Development International	www.sdi.co.uk

APPENDIX B-2 - MHK Technologies and Projects

The following is a synopsis of several active MHK projects that include different technologies both in the U.S.

Ocean Renewable Power Company (ORPC)
Projects in Maine, Alaska, Florida, Canada
According to ORPC's website, ORPC power systems are designed around a proprietary Turbine Generator Unit, or TGU. The TGU works on the same principle as a wind turbine, with rotating foils that power a central permanent magnet generator. Since the unit is installed underwater, and water is more than 800 times more dense than air, the ORPC TGUs provide significantly more power than wind turbines at relatively low water current speeds. The units are built primarily with composite materials to resist corrosion in fresh and salt water and incorporating gearless units, they require no lubricants.

At river and ocean energy sites, ORPC installs TGUs in groups, to form complete power systems that convert river and ocean energy into grid-compatible power. The TGU has a modular design that makes it easy to adapt to the varying needs of different site environments, as well as to configure it differently depending on where it will be used. To install power systems at small river and shallow tidal sites, arrays of TGUs would be secured to the riverbed or seabed using bottom support frames. To deploy the technology at deeper tidal and deep ocean current sites, the design would "stack" several TGUs together to form larger, more powerful modules, moored to the sea floor with a deep sea mooring system. Because the modules are buoyant, they are suspended above the sea floor at a depth that's safe for both sea vessels above and sea life below.

Since 2006, ORPC has been working with the Federal Energy Regulatory Commission (FERC) to secure the necessary permits to deploy the Maine Tidal Energy Project and to commercialize the ORPC TidGen™ Power System. In the first half of 2012, ORPC received a FERC Hydrokinetic Pilot License for the installation of the Maine Tidal Energy Project by installing a commercial TidGen™ Power System in Cobscook Bay. After running and monitoring this initial system for a year, ORPC will install additional power systems over the ensuing three years to increase the project's capacity to three megawatts (MW) – enough electricity to power 1,200 Maine homes and businesses with clean tidal energy. This project is supported in part by a U.S. Department of Energy (DOE) grant. Please see www.orpc.co for more information.

Open Hydro
Projects in Nova Scotia and Washington State
Nova Scotia Power (NS Power) *- Open-Center Tidal Turbine Demonstration (Nova Scotia, Canada)*
Nova Scotia Power has partnered with Irish firm Open Hydro to explore a new source of tidal energy for Nova Scotia. As part of a test project that will help to determine the feasibility of harnessing tidal energy on a commercial scale, NS Power has deployed a ten-meter, 1 MW in-stream tidal turbine in the Minas Passage of the Bay of Fundy – home to the world's most powerful tides.

The Open Hydro turbine is self-lubricating and operates without oils, grease and other fluids which could impact the sensitive marine environment. The turbine's open-center design allows sea life to freely pass through the device, a feature that should ensure minimal impact on its surrounding environment. The machine was deployed in 2009 and retrieved after a short operating period. In the future two additional turbines will be deployed in the Bay of Fundy by Clean Current from British Columbia and Minas Basin Pulp and Power of Hants East. These companies, along with NS Power, are all members of the Fundy Ocean Research Centre for Energy (FORCE), which is in the process of constructing a station that will allow the turbines to be connected to the electrical grid. The station will also include a research laboratory to examine the data collected from the test turbines in the hope of determining how best to harness energy from the Bay of Fundy in the future.

The Open Hydro turbine technology is also proposed at the SnoPUD tidal energy project in the Puget Sound, where a FERC Draft License Application (P-12690) was submitted in February 2012. Please see:
www.nspower.ca/en/home/environment/renewableenergy/tidal/projectoverview
http://www.snopud.com/powersupply/tidal.ashx?p=1155

Hydro Green Energy
Mississippi River
Hydro Green Energy, LLC (HGE) is a privately-held renewable energy development company with proprietary hydropower technology. Hydro Green Energy focuses on developing new hydropower generation at existing non-powered dams. At "low-head" hydropower sites (head of less than 30 feet), HGE deploys a "plug-and-play" modular hydropower solution that minimizes the civil work and the time consuming, costly installation process of conventional hydropower.

The foundation of HGE's technology, which is known as "Lock+™" or "Dam+™," was successfully demonstrated at its hydrokinetic power project in Hastings, MN (FERC P-4306). With its unique approach to hydropower project development, HGE will unlock scores of low-head hydropower sites that have been uneconomic to develop over the past several decades. HGE is presently developing 28 hydropower projects in 14 states. The company's project pipeline will result in the development of nearly 300 MW of clean, renewable energy. Please see: http://www.hgenergy.com/technology.html.

Free Flow Power
Mississippi River
Free Flow Power (FFP) is currently working towards licensing 25 permitted projects in the Lower Mississippi River between Kentucky and Louisiana. Additionally, FFP has 43 preliminary permits pending before FERC. The powerful currents of the Lower Mississippi render it the ideal environment for in-stream hydrokinetic development. The 25 permitted Projects in the Mississippi would generate 3,303 MW; and the total nameplate capacity for the 43 pending sites is 5,371 MW. Please see: www.free-flow-power.com.

APPENDIX C - New York State Marine and Hydrokinetic Case Study: The Roosevelt Island Tidal Energy (RITE) Project

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Note: The full body of case study data on the Verdant Power Roosevelt Island Tidal Energy (RITE) Project is available in the company's December 2010 Final License Application to FERC (P-12611) available at www.theriteproject.com. Other details are summarized in a March 2011 NYSERDA Environmental Monitoring, Evaluation and Protection (EMEP) Project report, Roosevelt Island Tidal Energy (RITE) Environmental Assessment Project available at: www.nyserda.com/publications/11-04-roosevelt-island-tidal-energy.pdf.

SUMMARY

Since its inception in 2000, Verdant Power has advanced the state-of-the-art in Marine and Hydrokinetic (MHK) research and demonstrated the utility and efficiency of a water-to-wire turbine system in converting the kinetic energy in flowing water into electric power, with concurrent environmental permitting and assessment. During 2006-08, Verdant Power conducted a demonstration of its proprietary Kinetic Hydropower System (KHPS) at the company's Roosevelt Island Tidal Energy (RITE) Project, located in the East River in New York, NY. During the RITE demonstration, the KHPS met expectations, showing a turbine peak efficiency of 38 to 44 percent in water current speeds of 3 to 7 feet/sec (1.8 to 4.2 knots) while delivering emission-free, renewable electricity to two commercial end users.

During the RITE demonstration, Verdant Power also conducted environmental monitoring efforts required under project permits, advancing the understanding of fish presence, abundance, species characterization and fish interaction with operating MHK turbines. The results of this effort culminated in the December 2010 filing of a Hydrokinetic Pilot License Application with the Federal Energy Regulatory Commission (FERC) for pilot development of the RITE Project (FERC No. P-12611).

Overall, the environmental assessment conducted during the demonstration has laid the groundwork for the commercial deployment and environmental monitoring of the KHPS at the RITE Project and other sites in New York and the U.S. under the federal and state regulatory system. Additionally, the monitoring protocols and results stand as a model for addressing environmental compatibility issues for application of the Verdant technology at other sites in Canada, the UK and the rest of the world, as MHK projects continue to be developed. The application of the KHPS at RITE may ultimately provide a new and indigenous source of clean energy for New York State residents, as well as potentially establish a new stream of economic development for New York State businesses.

1. Verdant Power Technology: Kinetic Hydropower System (KHPS)

A. KHPS Technology

In order to maximize the application of its technology within the global marine and hydrokinetic (MHK) energy resource, Verdant Power has designed its Kinetic Hydropower System (KHPS) as a simple and uniquely scalable system that can be operated in tidal, river, and ocean current settings. As represented by the company's current projects, Verdant Power's technology can be applied in sites worldwide, ranging from shallower, near-shore tidal sites, such as the East River in New York (RITE Project), to the high velocity river flow of the St. Lawrence River in Ontario (CORE Project), and the deeper off-shore tidal waters of other sites worldwide. Attachment A provides a more detailed discussion of the salient environmental features of the KHPS technology.

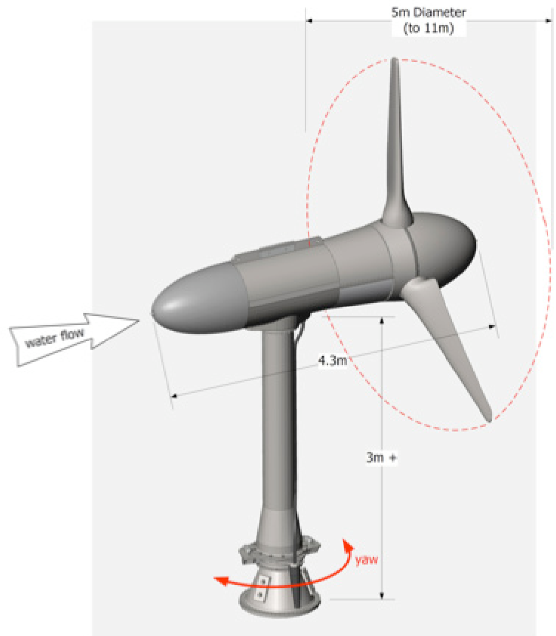

Figure 1. KHPS Turbine (Gen5)

The KHPS consists of three components:

1. The central component of the KHPS is a three-bladed horizontal-axis turbine (Fig. 1), which has four major assemblies:
   - A rotor with three-fixed blades that rotate at the relatively slow and constant speed of approximately 40 revolutions per minute (rpm), with tip-speeds of 35 feet per second. This is well below normal water vessel propeller speeds and conventional hydropower turbine blade speeds.
   - A sealed nacelle, pylon and passive yaw mechanism that are hydrodynamically designed to allow the turbine to self-rotate into the prevailing current flow (weathervane) so that the blades are optimally aligned to generate energy.
   - An enclosed generator and drivetrain within the nacelle serve as a horizontal-axis custom designed drivetrain unit that integrates the bearing housing with a special long-life planetary gearbox with mechanical shaft seals and a minimum of sealed lubricants.
   - A streambed mounting system, which can vary depending on site conditions, as a single monopile, triframe mount (holds three turbines), or single concrete gravity-based structure.
2. Underwater cabling, which is a low-voltage shielded cable of short distance and shoreline switchgear vaults, control room; and interconnection, which are underground or low-profile, small structures.
3. Appurtenant facilities for navigation safety and instrumentation, providing a navigational exclusion zone protected by Public Aides to Navigation (PATON) buoys and lighted warning signs.

B. RITE Project

Full descriptions of the Roosevelt Island Tidal Energy (RITE) Project demonstration, using Gen4 KHPS turbines, and the RITE Project pilot, using Gen5 turbines, are provided in detail in the RITE Hydrokinetic Pilot License Application (P-12611), which Verdant Power submitted to the Federal Energy Regulatory Commission (FERC) in December 2010, and which is available at http://www.theriteproject.com.

The RITE Project in the East Channel of the East River is shown in the photo below:

2. Regulatory Process at RITE

The ten-year history of technology advancement and environmental assessment through both federal and state regulatory processes at RITE is summarized on Figure 2 for the RITE demonstration, and Figure 3 for the FERC process related to the RITE pilot. Attachment B is a summary of the RITE Environmental Consultation List. The following is a brief synopsis of the efforts.

A. Initial Regulatory Consultations (2002-2005)

When Verdant Power first embarked on the development of the RITE Project in 2002, with the filing of a FERC Preliminary Permit for the RITE site in the East River in New York City, there was no precedent process in the U.S., neither regulatory nor environmental, to evaluate this new type of project and tidal technology. Verdant proceeded with the federal context of a FERC hydropower process, which requires the development of an Initial Consultation Document (ICD) under the FERC Traditional Licensing Process (TLP). Therefore, when in October 2003 Verdant issued its ICD, the discussion of the potential environmental effects of an MHK technology was new to both resource agencies and stakeholders.

In general, the opportunity for a new source of clean energy was well received during scoping meetings held in 2004, but it also raised significant concerns regarding the regulatory scheme for the grid-connected generation of such technology, as well as the potential environmental impacts of operation. In 2005, in order to demonstrate its technology and gather data that could begin to address these concerns, Verdant Power sought permission from FERC to test a six-turbine field of turbines in the RITE Project site in the East Channel of the East River (RITE demonstration). In a precedent-setting declaratory order (known as the 'Verdant order', FERC ruled that this activity did not require a license under the Federal Power Act, as it was consistent with the following findings:

1. *The technology in question is experimental;*
2. *The proposed facilities are to be utilized for a short period for the purpose of conducting studies necessary to prepare a license application, and power generated from the test project will not be transmitted into, or;*
3. *Displace power from, the national electric energy grid.*[16]

As such, the company was allowed to demonstrate the Gen4 KHPS at RITE and begin to develop operational and environmental monitoring data, provided that the demonstration project obtain all federal, state and local permits for such a temporary demonstration.

B. RITE Demonstration (2005-2008)

As discussed above, the 2005 'Verdant Order' allowed the RITE demonstration to proceed, though also required the acquisition of associated state and local permits. Thus, Verdant acquired and subsequently complied (and ultimately received amendments to as necessary) with the following three permits:

- U.S. Army Corps of Engineers (USACE) Permit (No. NAN-2003-00402-EHA).
- New York State Department of Environmental Conservation (DEC) Permit (No. 2-6204-01510/00001) (issued jointly with USACE permit).
- New York State Office of General Services Lease (No. LUW-01008-06).

These permits have and continue to permit the demonstration of the KHPS at RITE. As a condition of these permits, Verdant defined a specific Fish Monitoring and Mitigation Plan

[16] 111 FERC 61,024 – April 14, 2005; the "Verdant Order"

(FMPP) along with the definition of eleven study plans [17] to be executed before and during the demonstration. While most of the study plans were executed during 2006-07, some significant modifications took place after a June 2007 review of the efficacy of the fish monitoring protocols. This "adaptive management" effort resulted in a redefinition of the study protocols for use in the final phase of the RITE demonstration (Deployment 3).

C. RITE Project Transition (2008-2013)

Additional consultations in mid-2007 to early 2008 led to the redefining of the study protocols to be conducted during Deployment 3 of the RITE demonstration, conducted in the fall of 2008. The most significant was an effort to observe an operating (rotating) KHPS turbine for fish interaction and to "groundtruth" the data collected by fixed hydroacoustics. The information developed in this effort was provided in Verdant Power's Draft License Application (DLA) filed with FERC in November 2008. More detailed results were made public in a report to the New York State Energy Research and Development Authority (NYSERDA) published in March 2011. [18]

Based on the body of scientific observation, studies and results during the RITE demonstration, and the lessons learned, Verdant Power proposed a staged pilot project incorporating a set of environmental monitoring plans, termed the RITE Monitoring of Environmental Effects (RMEE) plans. This proposed approach and plans were reviewed and submitted by Verdant Power under its Final License Application (FLA) to FERC in December 2010 as the ongoing protocol for the RITE Pilot Project. The RMEE plans are available at www.theriteproject.com as Volume 4 of the FLA.

The FERC regulatory process, including Verdant's submission of its DLA and FLA, is displayed on Figure 2. As the RITE Project transitions to a staged development in the proposed pilot project under a FERC license, it would align with the regulatory structure outlined in the Verdant FLA. [19]

However, during this transition period, Verdant continues to maintain the RITE demonstration site as a viable permitted area to conduct two important Gen5 tests in the 2012-13 timeframe.

D. RITE Pilot Project (2011-2021)

As discussed above, Verdant Power completed and filed its FLA for the RITE Pilot Project on December 28, 2010 under FERC docket P-12611-005. The following is a synopsis of activity since then:

- FERC acted to accept the license and establish a process schedule. FERC issued an Additional Information request, and Verdant filed a response in January 2011.

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[17] Verdant's suite of RITE operational study plans included Fisheries (4 unique protocols); Underwater Noise, Hydrodynamics, Bird Observation, Water Quality Assessment, Benthic Habitat, Rare, Threatened and Endangered Species Assessment, and Assessments of Recreational Resources, Navigation and Security, and Historical/Cultural Resources.

[18] NYSERDA Roosevelt Island Tidal Energy (RITE) Environmental Assessment Project Final Report 11-04: March 2011 (Available at www.theriteproject.com.

[19] Please see Volume 1 of FLA for New York State and Volume 2 pg E-24 et al for Federal; and Pg E-184 for consistency discussions.

- NYSDEC/USACE 401/404/10j: Verdant filed the permit application for the Pilot Project in February 2011.
- Verdant filed the CZMA consistency form in February 2011 and received a Concurrence with Modified Consistency Confirmation letter on August 5, 2011.
- FERC issued a concurrence on ESA/BA on February 14, 2011 seeking NOAA response; NOAA filed a response letter May 10, 2011 (see below).
- Agencies/public filed comments on the RITE FLA - Recommendations, preliminary terms and conditions on March 4, 2011 (five letters received).
- FERC issued a single EA on May 3, 2011.
- At the request of the agencies, the Commission noticed and conducted a public teleconference on Adaptive Management on May 24, 2011.
- Verdant filed a clarification to the RMEE plans including the adaptive management understanding on May 28, 2011.
- Agencies and others filed comments on the FERC EA on June 2, 2011 (five responses were received).
- FERC conducted a pre-license inspection of the RITE Projecton May 31, 2011.
- NYSDEC acted to issue a Water Quality Certification (WQC) for the RITE Project on December 14, 2011.
- FERC acted to issue a ten-year Pilot Project License for the RITE Project (P-12611) on January 23, 2012.

Figure 2 - Regulatory Activity Related to RITE Demonstration

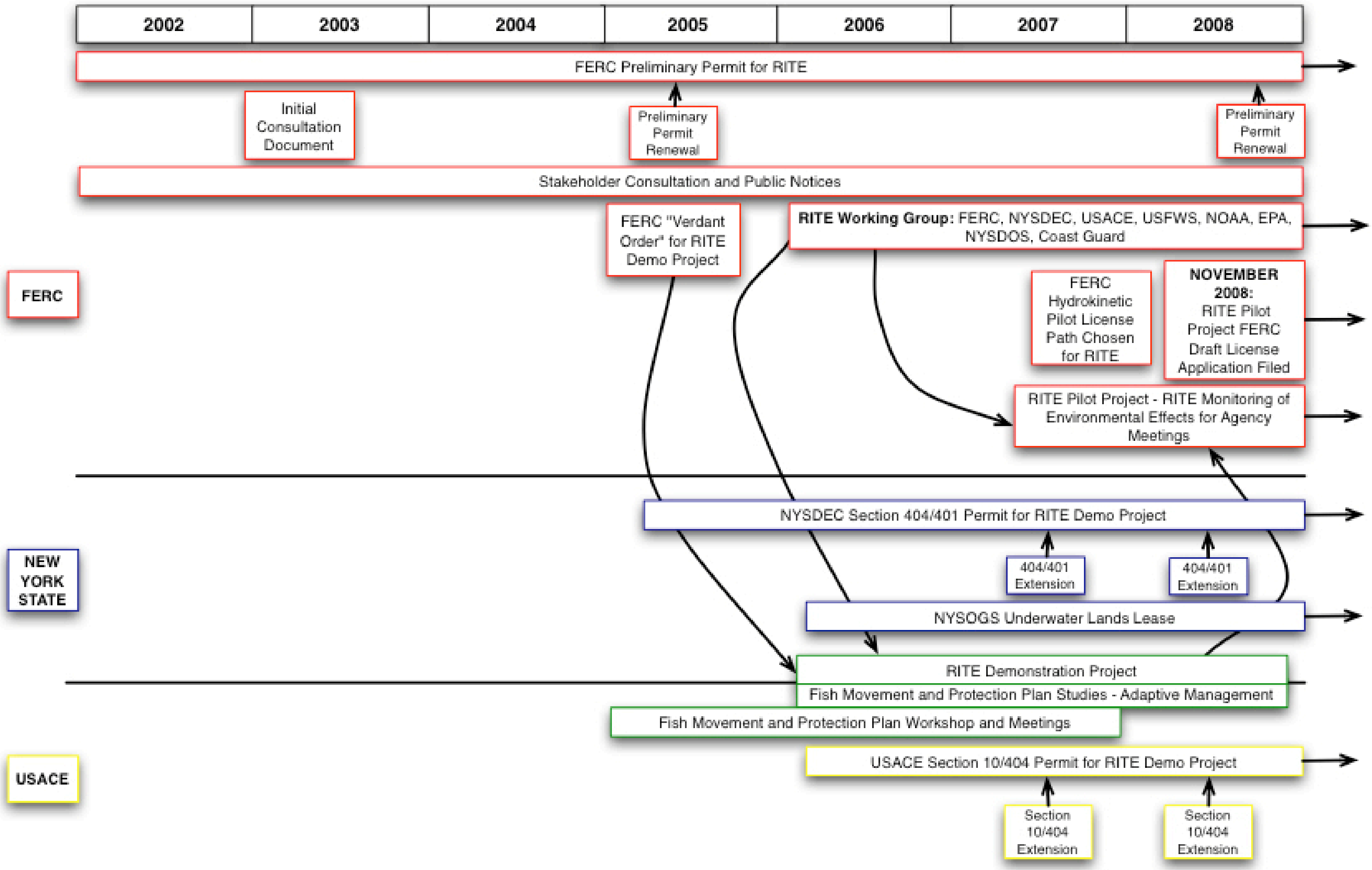
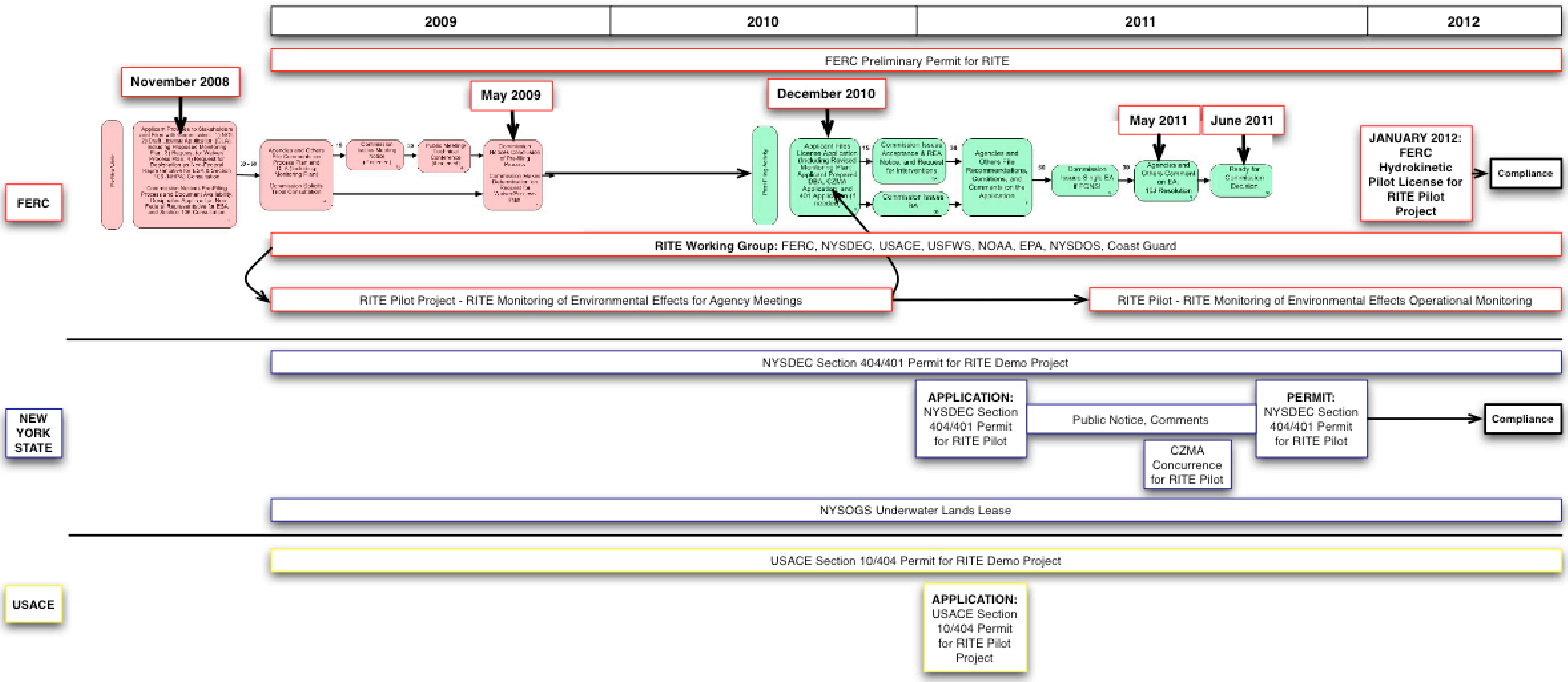


Figure 3 - Regulatory Activity Related to RITE Pilot Project



3. Key Environmental Issues at RITE

A. Early Consultations

The RITE regulatory and environmental consultation process is detailed in the correspondence logs contained in both the Draft and Final License Applications over a period of years extending back to 2002 (See Attachment B for a representative list). The initial broad range of issues, concerns and questions addressed in the ICD (2003) focused on the description of the RITE Project area and the concerns of stakeholders and agencies, mostly relative to the new technology. At the time, there was little peer-reviewed literature and/or fieldwork conducted, and Verdant relied on expert support from the DOE's Oak Ridge National Laboratory. A magazine article of the period, *What's the Future of Instream Hydro?* by Drs. Charles C. Coutant and Glenn F. Cada of the Oak Ridge National Laboratory, Oak Ridge, TN, published in *HydroReview* magazine (Volume 24, Number 6, October 2005), summarized a broad range of initial concerns, which Verdant addressed through the consultation process. These included concerns that are specific to the MHK technology and also to a proposed site (See Attachment C as representative FAQ on MHK technology).

The early consultation focused on education, examining how the new MHK technology would be installed, operated and maintained and the similarities – and significant differences – from conventional hydropower. Verdant sought to answer many concerns with scientific dialogue about the KHPS technology specifically and the RITE site in urban New York City.

As the RITE consultation continued, it became apparent that many of the concerns were focused on a large commercial project, not the planned demonstration of six 35kW turbines for an 18-month period, and so the dialogue became more focused around a National Environmental Protection Act (NEPA) process that allowed prioritized studies to answer concerns at a demonstration level.

B. RITE Environmental Studies During Gen4 Demonstration

A key aspect of the RITE demonstration (six turbines, 2006-08) was to assess the interactions of Verdant Power's KHPS with the environment. As the company installing the world's first full-scale MHK turbine array, Verdant worked with regulatory agencies and other key local stakeholders to develop and execute a number of study plans that have served as the basis for understanding the interactions and importance of moving forward with pilot and commercial scale MHK projects. During the demonstration, Verdant conducted a number of 'first-time' fish interaction studies to examine biological issues regarding the operation of the KHPS in fast waters.

The body of environmental work executed is quite large and to simplify this to a list of key agency and stakeholder concerns is truly unfair given the long history (2002 - time of writing) and the level of technical discussion and ongoing environmental monitoring that continues at the core of understanding how Verdant's technology will interact with the environment. However, in an effort to focus the discussion, Table 1 summarizes what has been resolved through the RITE demonstration as governed by the NEPA process, and what remains to be studied at the RITE Pilot Project, with detailed references available in the RITE FLA. Eleven studies and workgroups were executed in the context of the RITE demonstration, with results reported in the referenced section of the FLA, and with ongoing studies to be conducted during the RITE Pilot, as the six RMEE plans.

C. Relevance of Environmental Effect Monitoring Scale

Verdant Power's experience is that it is useful to consider the following terminology in developing relevant monitoring methods and protocols for its KHPS projects. This process includes examining key biological parameters (e.g., fish movement, migration, etc) and matching monitoring protocols at three different scales:

- Micro scale - in and around an individual turbine (1 diameter (1D) = 5m at RITE), rotating at <40 rpm and only during high velocity periods over 1 m/s. At this scale, resident and migratory fish interaction and micro hydrodynamics are being studied.
- Meso scale - in front/back of the turbine triframe. Here the reaction around a triframe of 3 turbines is being studied, as well as the interdependencies and recovery distance to the next triframe in the array, generally 12D (at RITE) to 20D (other sites) in distance
- Macro scale - well beyond the triframe (and the fully developed array) extending to points where organisms first sense/encounter the minor hydrodynamic presence of the KHPS array. This is a broader-scale study conducted for longer-term deployments.

This terminology is similar to other MHK industry practitioners that use 'near-field' and 'far-field' as reference points. However, it has been Verdant's observation that adding the within-array regions (meso scale) will likely be relevant as the industry begins to build arrays.

Table 1- Key Environmental Issues at RITE (Following NEPA structure; FLA References Included)

DLA Studies	Issues and Concerns	Verdant Studies and Results	Ongoing Issues to be Addressed in RITE Pilot
1	Water Quality: Conditions and potential for alteration	Water Quality Studies (2005-06) [Vol 2, pgs E-76-87]	
2	Benthic Habitat/ Essential Fish Habitat (EFH): Conditions and potential for alteration	Benthic and EFH Studies [Vol 4, EFH Appendix]	
1/2	Geology: Presence and changes in condition of substrate and potential for sediment transport/deposition.	Sediment Sampling/Mapping (2006) [Vol 2, pgs E-31-39]	
3	Hydrodynamics: Effect of project operation on water currents, directions and levels	Hydrodynamic Study (2005-07) [Vol 2, pgs E-46-76]	Water level monitoring [Vol 2 pgs E-76 and Vol 4 pg.6]
3	Aquatic Species – Movement: Migration and interaction, including strike by rotor blades	Fish Movement and Protection Plan (FMPP) (2006-09) [Vol 2, pgs E-87-109 and below]	

DLA Studies	Issues and Concerns	Verdant Studies and Results	Ongoing Issues to be Addressed in RITE Pilot
4	Species Presence and Abundance	[Vol 4, EFH Appendix]	RMEE-1: Seasonal Fixed Hydroacoustics& RMEE-2: Seasonal DIDSON Observation
5	Movement & Migration	[Vol 4, Appendix A]	RMEE-1: Seasonal Fixed Hydroacoustics
5	Interaction with KHPS & Strike by Rotor Blades	[Vol 4, Appendix B & Biological Assessment]	RMEE-2: Seasonal DIDSON Observation
6	Underwater Noise: Sound levels relative to aquatic species and noise during construction and operation	Underwater Noise Study (2005-07) [Vol 2, pgs E-96-110]	RMEE-6: Underwater Noise Monitoring and Evaluation
7	Avian (and Terrestrial) Resources: Interaction of diving and migrating birds with operating machines	Bird Observation Study (2005-08) [Vol 2, pgs E-111-122]	RMEE-5: Seasonal Bird Observations
8	Rare, Threatened and Endangered Species, specifically interaction of project with ESA-listed species: Shortnose Sturgeon and Sea Turtles	RTE observations (2005-08) [Vol 2, pgs E-122-131; Vol 4 - ESA for Shortnose Sturgeon, Atlantic Sturgeon[20], Sea Turtles]	Ongoing ESA consultation with agencies; RMEE-4: Tagged Species Detection [Vol 4]
9	Recreational Resources: Location of project with respect to recreation (boating) and fishing (recreational)	Convened Recreation Resource Group (2005-08) [Vol 2, pgs E-131-148]	RMEE-7 recreational study plan during pilot operation
10	Navigation: Location of Project with regard to navigation (commercial and transport)	Convened Navigation and Security Group (2005-08) [Vol 2, pgs E-148-158]	Ongoing consultation and RITE Safeguard plans [Vol 3 (CEII[21])]
11	Aesthetic Resources: Visual effects of the project infrastructure on identified resources	[Vol 2, pgs E-159-164]	

D. Results of Environmental Monitoring at RITE

RITE Demonstration Environmental Monitoring

As referenced above, Verdant used, and adapted, several different techniques during the 2006-08 RITE demonstration. This was a multi-faceted approach to achieving a scientific understanding of the environmental fishery interactions at the micro, meso, and macro scales. A brief synopsis of the methods and respective utility follows.

Fixed Hydroacoustics: An array of 24 split-beam transducers (SBT) around the KHPS array (micro/meso scale) provided continuous 24/7 data in a format that requires complex algorithms

[20] Atlantic Sturgeon are pending listing as ESA as of October 2010.

[21] Volume 3 of the FLA contains protected Critical Energy Infrastructure Information and is not intended for release.

and QA/QC and groundtruthing to ascertain abundance, presence and potentially behavior (with long data sets). The system had the downside of not being able to distinguish species and was a relatively expensive technique. However, two key lessons were learned:

1. Significantly fewer SBTs (1-3) provide an adequate sense of the presence and abundance (as well as target size) of migration pattern observation at the meso/macro scale for pilot operating arrays, and
2. 24/7 monitoring is not required, but rather seasonal limited deployments provide necessary characterization of the presence, abundance and movement.

The large body of information developed by this 24-transducer array developed presence and abundance data as presented in the RITE DLA. Two significant findings were developed from this body of information:

- Data collected during RITE demonstration showed that resident and migrating fish avoid zones of presence of the turbines and tended to populate inshore and slower moving water zones. Some possible avoidance behavior was noted at the meso scale when turbines were operating.
- Data collected about zonal and tidal spatial and temporal presence suggests that fish behavior is influenced in the channel predominately by the natural tidal currents and only secondarily by the presence of rotating KHPS turbines. Fish are observed active at slack tide and transitions from slack to ebb and flood; and less when the turbines are operating (water velocities over 0.8 m/s).

Mobile Hydroacoustics: Multiple day and night transects using an SBT were run over a period of 14 months to attempt to characterize fish size and usage of the macro area around the demonstration for presence/abundance and migration patterns. As detailed in the RITE DLA (page E-97), the mobile data was not generally useful since it represented a "snapshot" in a variable environment with no information on species, only size. It was an expensive ($250,000+) effort that yielded little knowledge and therefore was agreed to be abandoned as part of the adaptive management consultations in June 2007.

Stationary and Mobile DIDSON: The use of a Dual-Identification Sonar (DIDSON) system, which uses high definition sonar to produce a near video-quality graphic display in both short-term stationary and mobile observation modes, was employed at RITE with varying degrees of success. Stationary deployment was at a distance from the operating KHPS and while providing exceptional video, was only useful and cost effective for short-term (2-3 wk) observations, since both hardware and software have significant implementation costs as well as video interpretation and analysis costs. An alternative use for this expensive device was designed and implemented by Verdant in conjunction with the agencies. The Vessel-mounted Aimable Monitoring System (VAMS) incorporated both an SBT and DIDSON mounted in a downward looking orientation to observe an operating turbine.

During October 2008, with two turbines operating, the VAMS was deployed and video taken with a concurrent DIDSON camera and SBT, observing resident and migrating fish present in waters during slack, when the turbines were not operating. The observations also showed that fish were not present when the velocity of the water increased to greater than 0.8m/s and the machines were operating. Moreover, video did also observe, on one occasion, fish passing by the slowly rotating turbine blades along hydrodynamic flowlines, as predicted by free-body science. These observations, coupled with data gathered from the long-term stationary 24-SBT array around the six demonstration turbines, act as ground truthing to the observations of fish behavior and interaction with operating turbines that, as mentioned above, begin to lead to a body of scientific support that fish are not present in abundance near the zones of the operating KHPS, due to a combination of accelerated currents and detection/passage around machine flow lines when the KHPS is operating.

From these lessons learned, Verdant has focused on developing a cost-effective operational monitoring plan for the 30-turbine RITE Pilot field that will embody both SBTs for abundance and timing of migration patterns in the meso/macro scale, and also some use of DIDSON for micro/meso scale observation of operating machines. Clearly the VAMS does provide limited field exceptional quality visual images of fish behavior near the turbines for short-term deployments (a few days at a time). Its limitation is the difficulty in maintaining vessel position in the fast moving waters. A short-term stationary DIDSON deployment is currently considered the best observational option when KHPS turbines are operating and if there is a high abundance of fish present. This stationary DIDSON device observational protocol is the subject of a current NYSERDA environmental assessment contract undertaken by Verdant to observe an operating KHPS in 2012-13. This funding support is vital since the capital cost of the instrument, along with the on-water deploy/retrieve exercises and the cost to analyze the video in relation to the aquatic behavior, is significant. Therefore, it is important to weigh the likelihood of fish presence with the cost and safety concerns of the exercise, and the value of the data to be collected to advance the understanding of fish interaction with operating KHPS.

Baseline and Before and After Comparisons

While 'Baseline' and 'Before and After' comparisons comprised the initial environmental approach for studying the RITE demonstration, Verdant's opinion based on experience is that this concept is generally not applicable for studying effects of demonstration- or pilot-scale KHPS installations. While attempted at RITE (2005-09), the dynamic nature of the fast water does not allow for clean before-and-after observations, as in a river/dam environment. Most of the conclusions found at RITE were at a *de minimus* level that may not justify further effort on such comparisons. Findings included:

- *Fishery studies* – as detailed above, demonstrated that the most information was obtained not pre- and post-deployment, but through comparisons between operating and not-operating observations. Little was learned of snapshot baseline information.
- *Hydrodynamics* – pre- and post-model and field hydrodynamics were examined at all three scales (micro, meso and macro) as documented in a Verdant scientific paper.[22] Wake, pressure gradients, water level and velocity changes were documented, but at such low levels as to have minimal effects, even as predicted for a 30-turbine field, and as to be well below the precision available for most measurement devices.
- *Underwater Noise* – pre- and post-deployment studies found that aquatic species are presently living with noise levels generated by the existing navigable environment

[22] Colby, J. A., Adonizio, M. A., 2009, Hydrodynamic Analysis of Kinetic Hydropower Arrays, Waterpower XVI, no. 204. July 2009.

that is on par with the noise levels generated by up to 30 KHPS turbines. The likely impact on East River fish species indicate that the noise generated by the turbine array though audible to most species, would not cause injury.

- *Water Quality and Benthic* – pre-deployment studies were conducted and, based on the results, the consulting parties agreed that post-deployment studies would yield little additional information.
- *Bird Observation* – An exception to Verdant's comments regarding pre- and post-deployment studies is the Bird Observation study, which was conducted to assess whether the operation of KHPS turbines attracts diving birds to the site, an indicator of impacts to fish or a shift in fish swimming patterns. Through studies conducted during all periods of KHPS operation (9000 hrs), no apparent change in bird abundance, reaction or accumulation was noted. However, Verdant contends that visual observations of bird activity may be a useful tool moving forward with larger arrays as an indication of increased fish activity or bird feeding in a macro sense.

In summary, the RITE demonstration developed a body of scientific observation of fishery interaction with KHPS turbines operating at full scale, using a variety of techniques in close consultation with state and federal agencies and used adaptive management to modify the observational protocols over the course of the three-year effort. The lessons learned from this demonstration are important for moving the MHK industry forward. Given the complexities of both the installation and operation of a new technology and the application of relatively new and advanced techniques and protocols for in-water environmental monitoring, the RITE project, as supported by NYSERDA, led to many useful observations and lessons learned.

E. ESA Protected Species and Habitat Evaluations

Protected Species

Through ongoing consultation regarding the deployment of the demonstration turbines, NOAA Fisheries, NYSDEC, and the U.S. Fish and Wildlife Service (USFWS) have indicated that Atlantic sturgeon (a candidate species for Endangered Species Act (ESA) listing – pending as of January 2012) endangered shortnose sturgeon, threatened and endangered sea turtles, and harbor seals (protected under the Marine Mammal Protection Act) could be present in the area of the RITE Project. At the recommendation of NYSDEC, Verdant Power implemented a formal procedure for observations of protected species during the bird observation and hydroacoustic studies. Throughout the RITE demonstration, no observations were recorded. As outlined in the RITE FLA (Volume 2, Exhibit E), Verdant Power has summarized information on Rare Threatened and Endangered (RTE) data and conducted initial consultations. The RITE FLA also contains three Biological Assessments (BA) for review by FERC and the agencies.

Regarding the two fish species of sturgeon, as requested by the agencies, a key element of the BA is a KHPS-Fish Interaction Model that evaluates the potential for KHPS blade strike based on common lengths of the two endangered species. The development of this model is detailed in the FLA, Volume 4 Attachment 1. In February, FERC issued a concurrence with this assessment and in May 2011 NOAA/NMFS issued a letter affirming these conclusions stating, "*Based on the analysis that all effects of the proposed project will be insignificant or discountable, NMFS is able to concur with the determination that the approval of the proposed project by FERC is not* *likely to adversely affect any listed species under NMFS jurisdiction. Therefore, no further consultation pursuant to section 7 of the ESA is required."*

Essential Fish Habitat (EFH)

The Magnuson-Stevens Fishery Conservation and Management Act gave National Marine Fisheries Service (NMFS) the authority and responsibility for the protection of Essential Fish Habitat (EFH), which is defined as marine habitat essential to the health and production of federally managed species in marine and estuarine waters. As contained in the FLA (Volume 4, Attachment 2), Verdant Power and its contractor, Kleinschmidt Associates (KA), completed an EFH assessment for the RITE Project. The EFH evaluated the known specific habitat requirements for each of the listed managed species with designated habitat in the EFH area, which includes the East River, New York, and any potential project impacts to this habitat. Development of the EFH included information from the benthic habitat survey (existing habitat), mobile and fixed hydroacoustic fish surveys (fish species composition), and review of scientific literature in conjunction with project turbine deployment and operational information to assess potential project effects.

The findings of the EFH assessment conducted was to examine the EFH and EFH-managed species within the area influenced by the proposed project within the East River, including those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. The EFH assessment included a description of the proposed action; an analysis of the effects on EFH, EFH-managed species, and their major food sources; an evaluation of the effects of the proposed action on EFH and EFH-managed species; and proposed mitigation measures selected to minimize expected project effects if applicable.

Following review it was determined that designated EFH occurs in the area of the proposed project for various life stages (eggs, larvae, juveniles, adults) of 18 species. Four species have designated EFH for every life stage: windowpane flounder, winter flounder, scup and king mackerel. In addition, various life stages of red hake, Atlantic herring, bluefish, Atlantic butterfish, Atlantic mackerel, summer flounder, black sea bass, Spanish mackerel, Cobia, sand tiger shark, sandbar shark, clearnose skate, little skate and winter skate have been identified as having EFH requirements in the area of the RITE Project. None of these managed stocks are federally or state-listed endangered or threatened.

A full discussion of the results for each life cycle and species is presented in the FLA, Volume 4, Attachment 2.

4. Next Steps for Environmental Assessment at RITE

A. RITE Monitoring of Environmental Effects (RMEE) Plans

The RITE Pilot Project site would be located within a U.S. Coast Guard approved buoyed exclusion zone to recreational and commercial activity along the east side of Roosevelt Island, north of the Roosevelt Island Bridge. Under permits issued by DEC and USACE, the RITE demonstration collected data on the fish resources and found few if any effects from the operation of the demonstration turbines on aquatic resources. For the RITE Pilot Project, a set of aquatic resource monitoring plans, known as the RITE Monitoring of Environmental Effects (RMEE) plans, which are contained in Volume 4 of the FLA, has been developed in consultation with federal and state agencies. These plans will also maintain consistency with the intent of the New York Waterfront Revitalization Plan.

The RMEE plans are a comprehensive suite of monitoring efforts to evaluate the effects of operating KHPS turbines. Verdant Power is proposing the RMEE Plans as a multi-year program, conducted throughout the staged development (Installs A, B1/2, and C) of the RITE Pilot, with appropriate reporting and decision points at each stage. As part of the operational monitoring, Verdant Power will also install and record water velocity and level data with use of Acoustic Doppler Current Profiler (ADCP) devices, which will inform the evaluation of hydrodynamics of the machines and array. Specifically, the RMEE plans include:

RMEE-1: Seasonal Fixed Hydroacoustics - The deployment of seasonal fixed hydroacoustic instruments provide a picture, albeit incomplete, on species, on the meso and macro presence and abundance of fish targets in the pilot area and movement of fish relative to a turbine field at the meso and macro scales at a known migration period. Coupled with other elements of this plan, the interaction and effects of an operating KHPS can start to be understood.

RMEE-2: Seasonal DIDSON Observation Monitoring - The deployment of seasonal Dual-Frequency Identification Sonar (DIDSON), a multi-element sonar that provides video-like images of underwater objects is to provide real-time observation of fish behavior near operating KHPS during a seasonal period of known fish abundance. Specifically the goal is to provide imaging of any fish-KHPS interaction, both spatial and temporal, at the micro scale around a rotating turbine to build the understanding of fish interaction near operating machines.

RMEE-3: Seasonal Species Characterization Netting - The objective of netting is to provide a set of net capture data, during May through December with more effort during the seasonal period (mid-September through mid-December) of elevated fish abundance in the project vicinity to provide species characterization information in the area of the RITE Pilot, and to support the interpretation of the past and future DIDSON monitoring and hydroacoustic evaluations above.

RMEE-4: Tagged Species Detection - The objective of this plan is to provide new and unique detections on the potential presence of the proposed ESA listed Atlantic sturgeon, ESA listed shortnose sturgeon, along with striped bass, bluefish, winter flounder and other species that have been acoustically tagged. Detection would occur in both the east and west channels of the East River, proximate to the RITE Pilot project boundary. Little is known of the presence and pattern of these ESA species in the vicinity of the pilot project, and so this data will support further understandings of the effects of the operation of the initiative.

RMEE-5: Seasonal Bird Observation - The objective of this plan is to observe bird presence and activity near the RITE Project boundary in order to provide additional observations on the potential effects of the operating KHPS on diving bird populations, and also to provide additional insights into potential effects of an operating KHPS on the fish (i.e., increased bird activity in and around the RITE operating field could be an indication of increased injury and mortality of fish).

RMEE-6: Underwater Noise Monitoring and Evaluation - The objective of this study is to determine the noise signature from 6 to 30 operating Gen5 KHPS turbines and to use this information to verify or refute the initial finding that the machines do not emit noise at levels that would cause harm to aquatic resources.

The execution of this suite of environmental plans with operating KHPS turbines in place at RITE will provide ongoing evidence as to the environmental compatibility of this new technology with the environment.

B. Adaptive Management and the RITE Project[23]

In accordance with the FERC hydrokinetic whitepaper (April 2007), Verdant Power has developed the RITE Monitoring of Environmental Effects (RMEE) plans consistent with the intent of "adaptive management"[24] as defined by others. Adaptive management is used as an approach in environmental monitoring plans for MHK technologies because there are uncertainties surrounding the technology's impact on the environment, as well as uncertainties surrounding the efficacy of environmental monitoring approaches and monitoring technologies. Monitoring protocols are adjusted until clearly identified questions of environmental effects are answered (DOE EERE 2009). In the December 2009 DOE Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies, it is stated that adaptive management shares the following common components:

- Definition and quantification of the desired outcomes;
- Implementation, monitoring, evaluation; and
- Modification of the action, and re-evaluation through additional monitoring.

As discussed in Volume 4 of the RITE FLA and during the October 14, 2010 RITE agency workshop (notes from meeting in Volume 1 of FLA), the goal of the proposed RMEE plans is to:

1. Execute the plans – embodying the above elements to answer the questions outlined at the end of each RMEE plan;
2. Report on the results of its monitoring after each Install; and data collection effort;
3. Agencies will review the reports prior to the next stage (see page 7 of the Executive Summary of the RMEE plans – Volume 4 of FLA);
4. Adjust monitoring protocols if necessary if the monitoring is not providing sufficient answers to previously outlined questions (Please see "Summary and Key Questions" section of each RMEE plan);
5. Collectively recommend an action; either Continued Operation, Adjustment of operations, or, in accordance with the FERC whitepaper guidance, agencies could request that FERC order the Shutdown and removal of the project.

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[23] From "Proposed Content Insert of Verdant Power, LLC under P-12611," submitted to FERC on May 27, 2011 – See FERC docket (P-12611) for further detail

[24] Please see:
a) DOE EERE (U.S. Department of Energy, Energy Efficiency and Renewable Energy) Wind and Hydropower Technology Program. 2009. Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies. December 2009.
b) Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Verdant Power has managed the environmental monitoring of its RITE Project, from the demonstration phase to the development of the RMEE plans, using the philosophy outlined in the above steps, and will continue to apply the principles of adaptive management in the execution of the RITE operational monitoring plans required by the FERC Pilot license.

C. Summary of RITE Project Experience

Efforts conducted throughout the RITE demonstration and leading up to the proposed pilot project have provided challenging though invaluable learning opportunities for all involved – lessons that will continue to evolve as further operational monitoring continues. Several key takeaways from this experience follow:

- Throughout the RITE demonstration, the development and application of monitoring tools to observe the near and far field environmental effects was a significant undertaking. Adapting and deploying these monitoring protocols in a cost-effective manner will be a key element of the widespread use of the technology. This is recognized nationwide as a critical item for the MHK industry and is the subject of ongoing work supported by the DOE and NYSERDA.
- The regulatory process at RITE has proved to be a significant and lengthy process. It has however, been a duly transparent forum for consultation, public review, and sharing of environmental protocols, data and results. Indeed the published Verdant results and protocols are widely promoted and used by others in formulating other emerging projects worldwide. It is expected that, as the RITE Pilot advances, resulting reporting will continue and be informative to the industry. Similarly, as the MHK industry grows, the facilitation of data networking and broader access will become increasingly important. Indeed the efforts of the U.S. Department of Energy's project and technology database is a step in that direction, however the onus is on the developers and researchers to populate and use the database as a tool for understanding environmental effects of the technology.
- The RITE demonstration clearly embodied the concepts of "adaptive management" in the execution of studies in a collaborative and interactive manner. Moving forward with a pilot project, it is clear that adaptive management in the formulation and execution of operational monitoring plans will be a crucial component of project viability.
- While environmental monitoring can be accomplished, doing so cost-effectively remains a significant challenge. The need for cost-effective monitoring protocols is important when considering the development and deployment of a new technology by a start-up technology company. All MHK device developers like Verdant must bear not only the costs of technology development but also the environmental monitoring and associated regulatory activity. In most cases, costs for environmental monitoring alone far exceed the expected generation revenue (note that RITE demonstration was required to forego revenue generation altogether). As such, the RITE Pilot is a necessary "next step" in the progression to the commercial deployment of MHK technologies.
- Verdant seeks to continue on this path with the RITE Pilot Project to:
    - Continue to demonstrate the power generation, longevity and reliability of the KHPS technology;
    - Reduce technology costs through engineering, design and installation partnerships for O&M with the marine industry; and
    - Further demonstrate environmental compatibility through cost effective environmental monitoring for commercial installations.

ATTACHMENT A - Verdant Power Gen5 KHPS Turbine

Verdant Power has developed an improved fifth generation (Gen5) version of its KHPS turbine. This version is a redesign for commercial production, and is also based on operating experience from the Gen4 units demonstrated at the RITE Project, located in the East River of New York City. While the Gen4 units proved excellent performance in converting the energy in the water currents into grid-connected power, the Gen5 KHPS turbine is a design advancement aimed at high reliability, longevity, and cost-effective commercial manufacturing. It features a custom-designed integrated drivetrain (shaft/bearings/gearbox/generator/brake) with substantially fewer parts, and improvements in a number of areas.

Key design enhancements include the following, and are discussed below:

- Composite (FRP) Blades;
- Ductile Iron Hub Casting;
- Casting for pylon / nacelle connection;
- Integrated gearbox incorporating / shaft bearings / seals / planetary gearing, nacelle bulkhead and long-life lubrication system;
- Upgraded generator with custom mount;
- Failsafe brake;
- Redundant dynamic (shaft) and static sealing to retain lubricant and exclude water;
- Non-toxic fouling-release coating system; and
- Improved commercial quality control and assurance manufacturing process.

The Gen5 KHPS turbine and balance-of-system reaches commercial viability while enhancing environmental compatibility. At the time of writing, the Gen5 KHPS is currently in manufacturing and is planned for operation in 2013 at the RITE Pilot Project.

Composite Blades and Ductile Iron Hub Casting

Verdant Power has developed an entirely new rotor design for high-strength long-life FRP blades to extend its state of the art rotors to capture energy from higher water velocities ($\geq$4m/s) and deeper resources that can accommodate larger rotor diameters (6-11m), and significantly greater power levels. This design is supported by the DOE National Renewable Energy Laboratory (NREL) and Sandia National Labs (Sandia) under the DOE's Advanced Water Power Projects program. This design process included hydrodynamic and structural modeling and analysis, along with design for manufacture and fabrication technique development. Prototype blades have been fabricated and at the time of writing are undergoing extensive strength and fatigue testing on the test stand at NREL. Full-scale in-water hydrodynamic testing on a Verdant Power dynamometer is planned for completion at RITE in 2012.

Revised Pylon/Nacelle Connection

For the commercial-class Gen5 turbine, the pylon/nacelle connection has been redesigned as a casting for improved cost-effectiveness in volume production, and assembly. With the integrated drivetrain components, this casting, along with the integrated gearbox/bearing housing, and a redesigned upstream bulkhead, essentially comprise the entire nacelle, eliminating the original steel tube and many fabrication steps. The overall nacelle shape, including the FRP nose cone has been reduced in length by about 25 percent compared to the Gen4 design (See Figure A-1).

Integrated Gearbox/Shaft/Seals/Bearings

In place of the former off-the-shelf drive train components, the Gen5 turbine features a custom-designed unit that integrates the bearing housing with the special long-life planetary gearbox. At the rotor end, this unit also incorporates the new redundant high-performance mechanical shaft seals and proprietary sealing arrangement. At the high-speed end, the upgraded generator is directly mounted along with a failsafe brake described below.

The unit's cast iron housing mates directly to the pylon/nacelle casting and all seals are redundant. Each drivetrain unit will undergo bench dynamometer testing prior to deployment, and the new design will simplify and speed near-site final assembly, and subsequent maintenance operations.

Rotational Speed and Braking System

Under normal power generation operation, the Gen KHPS rotors, which have fixed pitch blades, rotate at a nearly constant speed of approximately 40 rpm, with tip-speeds on the order of 10.5 m/s (34.5 fps), which is very slow in comparison to vessel propellers operating in the water or conventional hydro turbines. By design, the blades do not cavitate.

In the tidal version of the unit, the KHPS turbines passively yaw (rotate azimuthally) so that the rotor is always in a downstream position relative to the turbine mounting whenever there is a significant water flow and velocity. The river (unidirectional) version has a fixed pylon and does not yaw.

The Gen5 turbine includes a brake, which limits the rotation rate (and the thrust loads on the rotor blades, turbine, mounting structure, and foundation) under conditions such as a loss of line load, or extreme water velocity. It requires a somewhat different operational control strategy from the Gen4 turbine. The brake is a "failsafe" type (spring-applied, electrically-released), so the default, unpowered position of the brake is "on" and the rotor is stopped. The brake is automatically controlled so that the rotors are only released to rotate when they are ready to generate, both in terms of adequate water speed (as indicated by a pair of array ADCPs), and all electrical parameters of the KHPS and the grid. This eliminates all pre- and post-generation rotation, avoiding rotation at speeds higher than normal generation speed, and reducing the total time the rotors actually rotate. The Gen5 turbine brake is released automatically during normal generation, and is automatically applied on any failure of the generator, cable, control system, interconnection or the electrical grid itself. Under a condition of any malfunction of the generator or electrical system, the brake power is removed, stopping the rotor within a few seconds.

Additionally, the turbine specification requires that even on loss of load at full power generation, the brake application will limit the transient (a few seconds) rotor speed to a maximum of 20 percent above normal speed (48 rpm) prior to its stopping the rotor. The brake can also be manually applied via a remote signal from the Control Room that cuts power to any generator. This mode is useful during commissioning, testing and for maintenance or security operations.

Operation of the turbine rotor brake beyond the basic control functions described above (i.e., electrical system faults or testing) can shorten the life of both the brake and the turbine. Accordingly, there is no provision for integrating the brake operation with a signal from another type of instrumentation. Such a mode of operation is not advisable due to the limitations of the sensing devices and sensing strategy, and the effect on the life of the turbines.

Lubricants

The Gen5 KHPS turbine uses a single common forced and filtered circulating lubricant for its gearbox and main bearings. The gearbox and bearing oil chamber contain approximately 34-38 litres (9-10 gallons) of lubricant. The lubricant is a Mobil SHC 100 percent synthetic (PAO-type), ISO grade 220 gear oil. This is suited to the severe conditions with potential moisture, and has good seal compatibility, corrosion and oxidation resistance, and thermal stability for long life between changes. It is rated as non-toxic and food-grade.

For containment of this oil, and exclusion of water, the main shaft has dual high-performance mechanical face seals, one to contain the oil in the oil chamber, and one to exclude the external water. Between the two face seals is an oil-compatible barrier fluid (also food-grade) chamber that would allow any leakage of water to accumulate in nacelle separate chamber. A sensor detects water ingress into the oil, and at a certain point, the turbine can be shut down and ultimately retrieved and maintained. No hydraulic fluid or other fluids are used.

Anti-fouling Coating System

Most of the turbine structure must be coated to prevent corrosion and biofouling. For the Gen4 units, this generally involved an epoxy coating for corrosion protection, with an outer copper-based anti-fouling coating. For the Gen5 turbines, Verdant intends to use a new silicone-based anti-fouling coating system that is non-toxic, and is currently testing such coatings in partnership with a coating supplier.

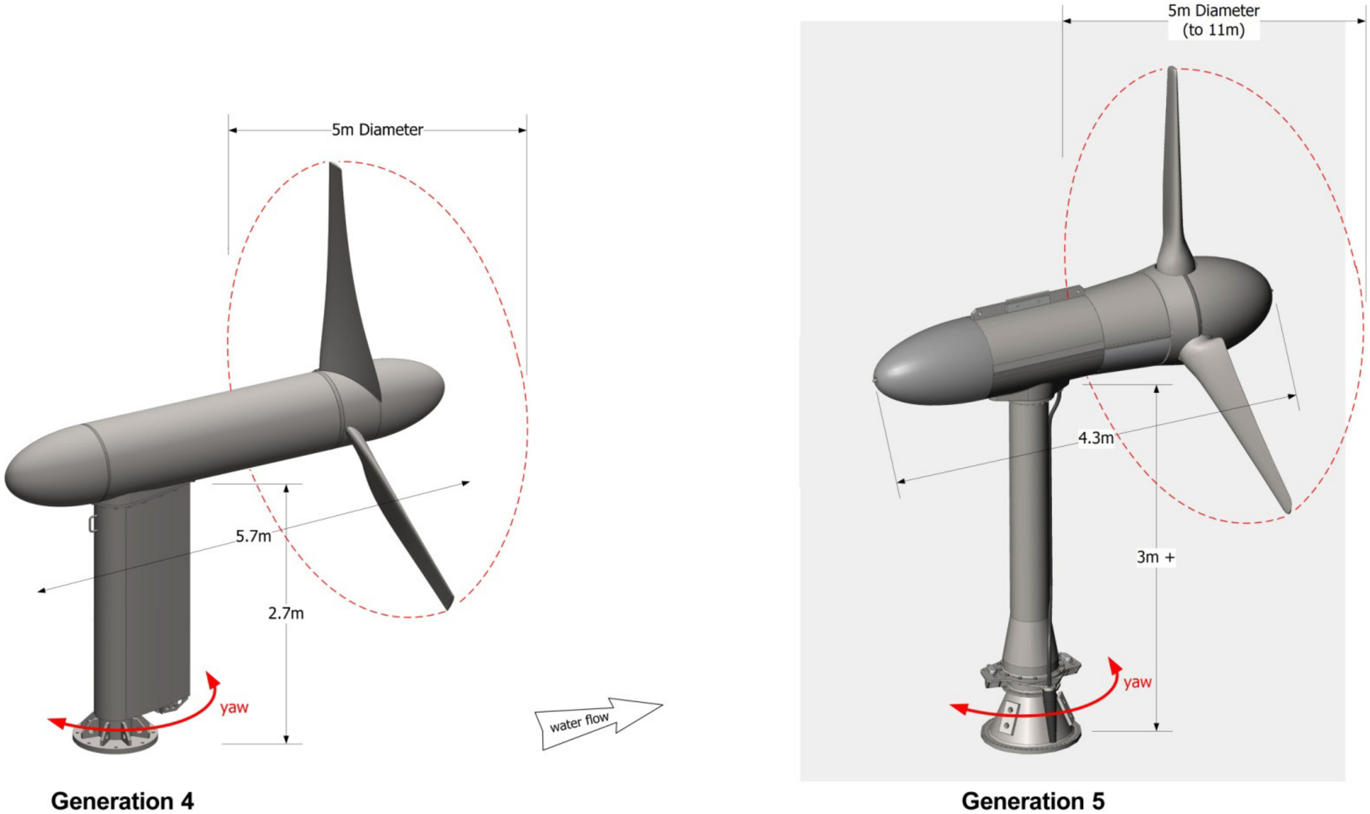

Figure A-1 - Comparison of Gen4 and Gen5 KHPS Turbines

ATTACHMENT B - RITE Environmental Consultation

When the RITE Project was initiated, outreach was made to a comprehensive list of federal, state and local agencies, as well as interest groups and organizations including those listed below (Please note that this list is not intended to be all-inclusive, or to preclude any group that is not listed from participating in the ongoing RITE Pilot licensing process).

New York City

- NYC Department of Environmental Protection (NYCDEP)
- NYC Department of City Planning (NYCDOP)
- NYC Economic Development Corporation (NYCEDC)
- Community Boards for New York and Queens County
- Roosevelt Island Operating Corporation (RIOC)

Agencies of the State of New York and Connecticut:

- New York State Department of Environmental Conservation (DEC):
    - – Office of Natural Resources and Water Quality, Division of Fish, Wildlife and Marine Resources (DFWMR)
    - – Office of Administration, Division of Environmental Permits (DOEP)
    - – Office of Natural Resources and Water Quality, Division of Water (DOW)
    - – New York/New Jersey Harbor Estuary Program (NY/NJ HEP)
    - – New York Natural Heritage Program (NYSNHP)
- New York State Office of Parks Recreation and Historic Preservation (NYSOPRHP)
- New York State Energy Research and Development Authority (NYSERDA)
- New York Power Authority (NYPA)
- New York State Department of Transportation, Office of General Services (DOT)
- Connecticut Department of Environmental Protection, Long Island Sound Program (LIS)
- New York State Department of State, Division of Coastal Resources (DOS)
- Port Authority of New York/New Jersey

Agencies of the United States:

- Federal Energy Regulatory Commission, New York Regional Office (FERC-NYRO)
- U.S. Department of Interior (U.S. DOI), including:
    - – U.S. Fish and Wildlife Service (USFWS)
    - – U.S. National Park Service (USNPS)
    - – Bureau of Indian Affairs (BIA)
- NOAA National Marine Fisheries Service (NOAA-NMFS)
- United States Army Corps of Engineers (USACE)
- United States Environmental Protection Agency (EPA)
- United States Department of Energy (DOE)
- United States Coast Guard (USCG)

Non-Governmental Organizations:

- Riverkeeper
- New York Rivers United (NYRU)
- National Audubon Society (national and/or local chapters) (NAS)
- American Rivers (AR)
- New York State Conservation Council (NYSCC)
- Natural Heritage Council (NHC)
- Environmental Resources Trust (ERT)
- National Hydropower Association (NHA)
- Low Impact Hydropower Association (LIHA)
- Roosevelt Island Residents Association (RIRA)
- American Council on Renewable Energy (ACORE)
- Keyspan Ravenswood Power Plant

Native American Tribes

- The Delaware Nation

ATTACHMENT C - Frequently Asked Questions about RITE Kinetic Hydropower Systems

As discussed, the history of consultation at RITE has addressed many of the issues and concerns related to the Verdant Power KHPS and the RITE site. However, the following are some questions that are relevant to MHK development in general. Citations to existing reference material are made for further information.

Can MHK technologies cause damage to fish and other aquatic animals from water pressure changes, cavitation, shear stress, or turbulence?
The answer to this question will vary with the type of technology installed. The mechanisms mentioned are largely due to entrainment, entrapment and entanglement with devices that have moorings, ducts, or shrouds.

Verdant Power KHPS turbines by design do not have penstocks, ducts, shrouds, intakes or screens. As discussed in early consultations for the RITE Project, the damage/injury to fish by water pressure change, cavitation, shear stress or turbulence mechanisms was understood to be not applicable.[25] In particular, the Verdant KHPS turbine rotor is designed not to cavitate under the range of operating conditions.

Verdant did incorporate observation for fish/injury into the Fish Monitoring and Protection study plans during the RITE demonstration. No effects from these mechanisms have been observed to date [FLA, Vol. 2, pg.E-96]. Blade strike as a potential damage/injury mechanism is still under study at RITE, but no evidence through 9000 operating hours has been observed.

Can MHK technologies cause changes in water temperature and thermal stratification, or changes in dissolved gases or chemistry?
Given the extremely energetic and dynamic conditions of the high velocity water at prospective MHK sites, thermal or chemistry issues are unlikely at the small project scale. While mixing phenomenon is important at a large project scale, the literature points to concerns only when significantly larger arrays of turbines are being considered.

As discussed in the RITE FLA, mixing in the water column in high velocity water has been studied by Verdant at the micro, meso and macro scales. The effects are extremely limited and water quality parameters are not considered an issue at the RITE site [FLA, Vol. 2, pg.E-82]. The total maximum theoretical heat input to the water from all turbine-related methods is *de minimus*. Any effect from rotating or stationary turbine rotors would be to increase mixing and reduce stratification, but will also be slight relative to this already highly turbulent and well-mixed resource.

Can the turbines 'heat-up' the water through friction?
This is primarily a theoretical question of moving turbines acknowledging an 'effect', but at the scale of installations contemplated in the MHK industry it is considered *de minimus*. The transformation of mechanical to electrical energy within the KHPS turbine nacelle is associated

[25] To be absolutely accurate there are changes in water pressure across the Gen5 KHPS turbine at a micro scale – however these pressure changes are orders of magnitude less than those in many conventional hydropower facilities.

with mechanical and electrical losses on the order of six percent of the power generated, which is ultimately rejected from the turbine as heat. Heat transfer is through the nacelle to the high velocity water at the micro scale, with volumes that result in immeasurable temperature rise in the water at the meso scale. As discussed in the RITE FLA, energy extraction or transfer is proven as a *de minimus* effect [FLA, Vol. 2, pg.E-17].

What about issues related toxicity of paints and antifouling coatings?
Marine industry paints and anti-fouling coatings have been used for years in various applications. As noted in the literature, the type and toxicity will vary with the coating technology utilized. At the RITE Project, the turbines have been coated with standard marine copper-based anti-fouling paint. Verdant plans to convert to non-toxic coatings as such coating developments and application methods are developed. Most likely in the medium term, the copper-based coating will be replaced by non-toxic silicone-based coatings. Due to these design considerations, short-term installation, and high dynamic velocities, it is generally agreed that the RITE Project does not pose any toxicity concerns.

Is there an issue with other pollutants entering the water?
As with any on-water activity, discharge from vessels servicing an MHK project is always a possibility, during installation and maintenance activities, but the risk is the same as with any vessel and precautions are in effect and spill incidents are regulated. Turbine lubricants and their containment will vary widely with the technology installed. At RITE, the KHPS turbine (Gen5) uses a single common circulating lubricant for its gearbox and main bearings and will contain approximately 34 liters (9-10 gal) of food-grade lubricant. This is primarily contained within the gearbox, with secondary containment by the nacelle itself. All static (o-ring) seals are redundant. The only dynamic seal, the main shaft seal, is a dual seal assembly, with high performance face seals both containing the lubricant and excluding seawater. Between these two seals is a food-grade barrier fluid chamber.

Are there potential issues with respect to generation of electromagnetic fields (EMF)?
As discussed in the literature, EMF considerations will vary widely with the technology installed and the length, voltage and design of the underwater cables, however it is still likely to be less than existing sources of underwater cables for other power and telecommunications services. At the RITE Project, the KHPS electromechanical parts are of low voltage and fully contained within a sealed box within the nacelle with air partially insulating the machines from the nacelle wall to the water. As such, very little leakage of EMF is expected. The underwater cables at RITE are low voltage (480V), low power (35kW rated) relative to other cables in the river, and short (<250feet) [FLA, Vol. 1, pg. A-13]. Due to these design considerations, the short-term installation, and high dynamic velocities, it is generally agreed that the RITE Project does not pose any EMF concerns.

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Marine and Hydrokinetic Environmental Policy Workshop Marine and Hydrokinetic Technology Background and Perspective for New York State

Final Report
December 2012

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