April 12

Phase II Cumulative Effects Framework Final Report

Prepared by
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On behalf of Oregon Wave Energy Trust

This work was funded by the Oregon Wave Energy Trust (OWET). OWET was funded in part with Oregon State Lottery Funds administered by the Oregon Business Development Department. It is one of six Oregon Innovation Council initiatives supporting job creation and long-term economic growth.

Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership funded by the Oregon Innovation Council. Its mission is to support the responsible development of wave energy in Oregon. OWET emphasizes an inclusive, collaborative model to ensure that Oregon maintains its competitive advantage and maximizes the economic development and environmental potential of this emerging industry. Our work includes stakeholder outreach and education, policy development, environmental assessment, applied research and market development.

www.oregonwave.org

CITATION

Parametrix. 2012. Phase II Cumulative Effects Framework Final Report. Prepared by Parametrix, Portland, Oregon. February 2012.

PROJECT TEAM AND SUPPORT

This work is funded by the Oregon Wave Energy Trust (OWET). OWET was funded in part with Oregon State Lottery Funds administered by the Oregon Business Development Department. It is one of six Oregon Innovation Council initiatives supporting job creation and long-term economic growth.

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The Cumulative Effects Analysis Framework is a joint effort between Parametrix and Aquatera. Parametrix is a 100% employee owned environmental consulting firm that focuses on solving complex environmental problems. Aquatera is a global leader in renewable energy analyses based in the United Kingdom.

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KEY TERMS

BASS	Bayesian Analysis for Spatial Siting
BOEM	Bureau of Ocean and Energy Management
CMSP	coastal and marine spatial planning
DLCD	Department of Land Conservation and Development
DOE	Department of Energy
Framework	Cumulative Effects Analysis Framework
GIS	geographical information system
NANOOS	Northwest Association of Networked Ocean Observing Systems
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OPAC	Ocean Policy Advisory Council
OWET	Oregon Wave Energy Trust
PaCOOS	Pacific Coast Ocean Observing System
RERA	Renewable Energy Resource Assessment
TSP	Territorial Sea Plan

EXECUTIVE SUMMARY

Phase 2 of the development of the Cumulative Effects Framework (Framework) accomplished several critical objectives. First, the "sensitivities" that were identified in Phase 1 were organized around an ecological function and ecosystem services framework, which facilitated communication and provided a more coherent structure. Second, the link between the data used and the scoring of the functions and services being evaluated was made more explicit through development of clear concept models. Third, concept models were used as a means of structuring dialogue with relevant stakeholders on several of the important functions within the system. This provided valuable feedback and greater consensus on how functions and services are being measured. The device suitability models are a particular example of this. Fourth, the data being used within the system was updated and improved.

The Framework also evolved considerably in unanticipated directions to adapt to circumstances during Phase 2 of the project. Phase 2 evolved in two distinct ways. First, two versions of the Framework were developed: the original RADMAPP version of the Framework, which is intended to provide easy access for stakeholders; and an ESRI-based version with expanded analytical capabilities that is intended for expert users. Second, the focus of system refinement shifted to updating conceptual models for siting wave energy devices in an economically constrained context. These changes made the tool much more relevant to the ongoing Territorial Sea Planning (TSP) process.

We anticipate that the Framework will continue to evolve as the context in which it is most often used and the nature of the questions it seeks to inform become clearer. To gain greater understanding of these issues, the next phase of Framework development will require completing a case study to test the tool based on a given scenario, and use the results of the modeling analysis to identify areas within the Territorial Sea that, if developed for wave energy, would result in the greatest change and/or generate the most impact. This case study is critical to testing the cumulative effect tool's ability to assist wave energy developers in making better choices for siting and operating wave energy facility development and operation.

1. INTRODUCTION

In 2008, the Oregon Wave Energy Trust (OWET) identified the need to create tools to assist the emerging ocean renewable energy industry in navigating the regulatory hurdles required of energy developers. One of the needs identified was a unified approach to understanding the environmental, social, and economic impacts and benefits associated with the growth of the renewable energy sector. This information is necessary for completing environmental reviews and processing permits required for development to proceed. The Cumulative Effects Analysis Framework was identified as a critical tool by OWET. This report documents the objectives, methodology, and tools created to assess the complex issues, impacts, and benefits associated with ocean renewable development. Further, this report documents how efforts to develop the Framework relate to the State of Oregon’s ongoing efforts to amend the TSP, which establishes the state policies, review standards, and program requirements for managing ocean resources, including marine renewable energy.

To understand the objectives and results of the Phase 2 analysis, it is beneficial to reflect on the project’s initial conception and the evolving need and opportunity to support ongoing efforts to zone Oregon’s Territorial Sea. That is, with OWET funding and support, the initial objectives of developing the Framework were two-fold: first, to develop a series of mapping and analytical tools that perform impact and effect analyses, and second, to use the Framework to inform the TSP process. Phase 2 of the Framework was originally envisioned as a natural extension of the work completed in Phase 1. During Phase 1, the data library, Framework, and user interface were developed, and the original intent was that Phase 2 work would supplement these efforts with additional data and improved system parameters to better understand the impacts, benefits, and tradeoffs associated with wave energy development scenarios to inform the development of relevant State policies.

Phase 2 evolved in two distinct ways: 1) the tool developed into two versions – one the original RADMAPP version, which is intended to provide easy access for stakeholders; and one ESRI-based with expanded analytical capabilities that is intended for expert users; and 2) the focus of the tool refinement shifted to updating conceptual models for siting wave energy devices in an economically constrained context.

Phase 2 of the Framework has resulted in the continued development of the data library, analytical framework, and improved user interface, as originally planned. However, the focus of the project has evolved from developing the Framework to integrating the Framework into the TSP process, to developing the Framework and informing the TSP process by providing stakeholders and decision makers with an improved understanding of the requirements for siting and operating wave energy devices in a pre-commercial or economically constrained environment. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability siting and operating wave energy devices reflect the financial importance of proximity to shore and a potential grid connection.

In large part, this change was driven by the actions of the Ocean Policy Advisory Council (OPAC), which is responsible for reviewing and recommending amendments to the TSP under ORS 196.443. It became apparent in fall 2011, when Department of Land Conservation and Development (DLCD) staff introduced the *TSP Resource Protection Criteria and Planning Options for Siting Marine Renewable Energy Development* report, that there was not an obvious mechanism for integrating the Framework into the TSP amendment process.

Thus, while the Framework is not currently being integrated into the TSP process, the Framework provides an unparalleled approach to evaluating the tradeoffs associated with coastal and marine spatial planning (CMSP), and has applications in parallel CMSP processes. For example, the Framework provides one of the formative building blocks of the Bayesian Analysis for Spatial Siting (BASS) tool being developed to assist the Department of Energy (DOE), the National Oceanic and Atmospheric Administration (NOAA), and the Bureau of Ocean and Energy Management (BOEM) to make responsible CMSP decisions.

The second chapter of this report describes the need for and ongoing efforts to update the Cumulative Effects Framework. The third chapter of this report summarizes OWET's ongoing efforts to inform the State's ongoing process to amend the TSP. The fourth chapter of this report describes recommended next steps for improving the relevance and use of the Framework in CMSP processes.

2. CUMULATIVE EFFECTS FRAMEWORK

2.1 INTRODUCTION

Cumulative effects analyses are a frequent source of challenge and difficulty in federal environmental review. Under the National Environmental Policy Act (NEPA), environmental review examines the direct and indirect effects of a proposed action along with the cumulative impacts. Cumulative impacts are defined as:

> *[I]mpact[s] on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. (40 C.F.R. 1508.7)*

In practice, the analysis of cumulative impacts is often only done at a project-by-project basis, and also after much of the analytical effort has been invested in the direct and indirect effects analysis. This leaves the comprehensive understanding of environmental impacts at a system-level to be one of the weaker links in the analysis. This both invites challenges from third parties, and is not a sound ecosystem or environmental management approach. In developing this cumulative effects methodology, the goal is to both integrate direct and indirect project impact analysis along with a scenario-based cumulative impacts analysis.

This approach also allows for an open debate and discussion on methods and assumptions that normally would be handled with each project applicant. By investing early in this process, the goal was to develop a comprehensive approach to evaluating impacts and benefits of siting marine renewable energy devices without relying on individual applicants and developers. This approach allows a more robust analysis process early on that integrates both the proposed impacts and effects from marine renewables, along with an understanding of the existing conditions and existing user impacts and effects.

2.2 MODELING REQUIREMENTS AND TOOL STRUCTURE

Three core components make up the Framework: a comprehensive data library, a decision-making engine, and the user interface. The data library is composed of over 1,200 datasets collected from the federal agencies, state agencies, research institutions, conservation organizations, and others. The decision engine is currently an impact matrix developed by Aquatera, referred to as the Renewable Energy Resource Assessment (RERA) tool. The RERA tool is a multi-criteria decision support tool designed to guide spatial analysis. As stated previously, the Framework currently has two versions: the original RADMAPP version, which is intended to provide easy access for stakeholders; and one ESRI-based with expanded analytical capabilities that is intended for expert users. ArcGIS provides end users the ability to combine the data library with the decision support engine to answer management questions and view the spatial outputs. Figure 1 demonstrates the general scheme used to structure the RADMAPP version of the Framework.

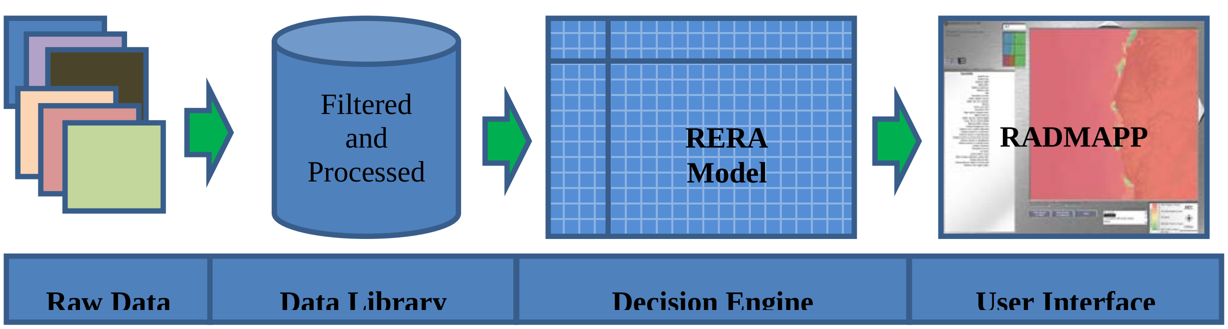


Figure 1. Cumulative Effects Model Structure

2.3 DATA AND DATA LIBRARY

At the onset of the project, members of the project team conducted a survey of available datasets that may be integrated into the Framework. The data collected were catalogued and reviewed by the project team to determine applicability in the modeling effort. This data review was conducted in parallel with the development of the wave energy model development. The data survey included outreach to existing data providers and distributors as well as contact with specific resource managers or data managers. Data was collected included datasets from:

- Mineral Management Service Marine Cadastre;
- National Oceanographic and Atmospheric Administration;
- Northwest Association of Networked Ocean Observing Systems (NANOOS);
- Oregon Department of Land Conservation and Development;
- Oregon Department of Fish and Wildlife;
- Oregon State University;
- Pacific Coast Ocean Observing System (PaCOOS); and
- Pacific Marine Fishery Management Council.

Additional datasets were also collected from individual agencies or industries such as sea cable data, utility infrastructure data, and marine shipping data. Social and economic data was also reviewed from more specific studies on coastal communities. These studies are referenced in subsequent sections.

2.3.1 Data Design and Requirements

The Framework is a spatially explicit model, designed to understand the various benefits and impacts of wave energy development on the Oregon coast. The model is generally structured to provide a one nautical mile resolution analysis of the Territorial Sea and outer continental shelf. However, the wave energy device feasibility models have a 10-meter-by-10-meter resolution. As the project searched for and evaluated data, several key criteria were included:

- Data inputs must have a geographic or spatial component.
- The spatial units must be of resolution and scale to match the project's analysis.
- The data must be documented, public, and trusted.
- Only secondary analysis is possible. Primary sources must be available and ready for use in the Framework.

These requirements resulted in some datasets requiring additional modeling or interpolation for inclusion in the extent used for this study. In some cases, the modeling was possible with techniques that are accepted; in other cases, the modeling was not performed because accepted methodologies were not available.

Data presented in this report are the inputs for the model. The model utilizes raster datasets for analysis. These inputs often required data processing and conversion for inclusion in the model.

2.4 DECISION ENGINE

The Aquatera RERA tool was developed over the past two decades for use in the United Kingdom. Aquatera is an international marine renewable consultancy based in Orkney, Scotland. RERA development was initiated to support renewable energy decision making and to investigate the relationships between uses and resources. The RERA component provides the decision-support engine for the Framework. The component links the various existing marine uses, natural and environmental resources, and other societal values to each life cycle component of marine energy development and across a variety of technologies.

The engine in RERA is based on creating qualitative relationships between sensitivities and activities. Sensitivities are physical, biological, social, or economic processes and resources. They include existing or future marine resources or uses that need to be studied in the analysis. These are categorized by five types:

1. Physical
2. Ecological
3. Conservation
4. Social
5. Economic

Each of these categories includes three potential levels of analysis. The first level includes the "attributes" that describe the ocean condition. This could include bathymetry, substrate composition, distance from a port, or a variety of other physical conditions. The attributes determine the extent to which natural processes ("ecological functions"), like species support or sediment transport, are performed. The functions performed by the ocean provide a variety of "ecosystem services" the coastal communities and others depend upon, such as commercial fishing, recreation, renewable energy production and water purification.

Concept models are developed to describe the how identified attributes contribute to the performance of functions. Additional concept models describe how attributes and functions support the ecosystem services communities rely on. The attributes identified as being necessary to support function performance or provide services are the focus of data collection efforts. The end result of this exercise is a standardized and documented understanding of how ocean conditions contribute to the ecological processes and human uses that we seek to measure. Detailed information on Functions and Activities is provided in the "Functions and Activities, Impact Matrices" section below.

Activities are then compared against the conditions needed to support the ecological functions and human uses modeled in the database. Activities are the technological or operational aspects of marine renewable energy development that occur throughout the life cycle of the technology. For example, activities include the port-side requirements for storage and vessels during construction, the various anchoring and energy absorbing technologies during operation, and the decommissioning actions required at the end of the project's life. These various aspects of the lifecycle interact with users and marine resources differently and need to be understood separately.

The database tracks the relationships between ecological functions/services and activities though a qualitative scale from a very high level of negative impact to a very high level of positive impact. This qualitative scale assists users in more easily communicating the nature of the impact. When possible, specific examples are documented. These examples may capture an outcome-based measure of the impact, such as a level of lethality or measurement of lost resource. These qualitative values are then mapped over to a logarithmic scale for analysis in the decision engine. The very high negative impact is mapped to the lowest values, and the positive benefits to the higher values.

Once the datasets are assigned to the relationships, the decision engine can provide spatially explicit outputs. The engine informs the combination of the data inputs through a product of all of the relationships present in the study area based on the lifecycle stage and energy technology type.

2.5 USER INTERFACE

The Framework has two user interfaces: the original RADMAPP user interface and the more advanced user interface developed in ESRI's ArcGIS desktop geographical information system (GIS). This interface uses a series of geodatabases, model builder tools, and preformatted map documents to assist spatial analysts in using the full functionality of the modeling.

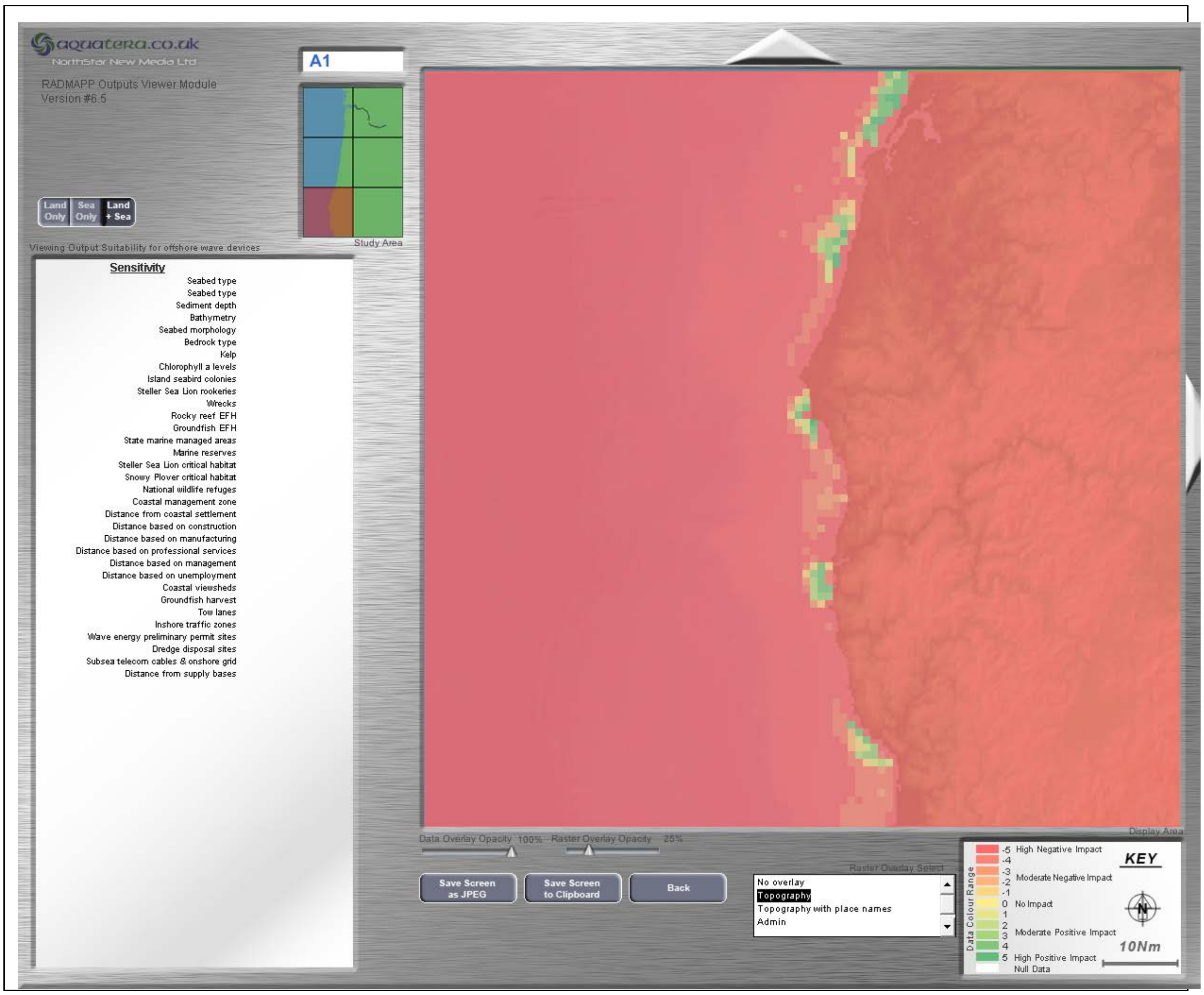


Figure 2. Screenshot of Cumulative Effects Framework in RADMAPP

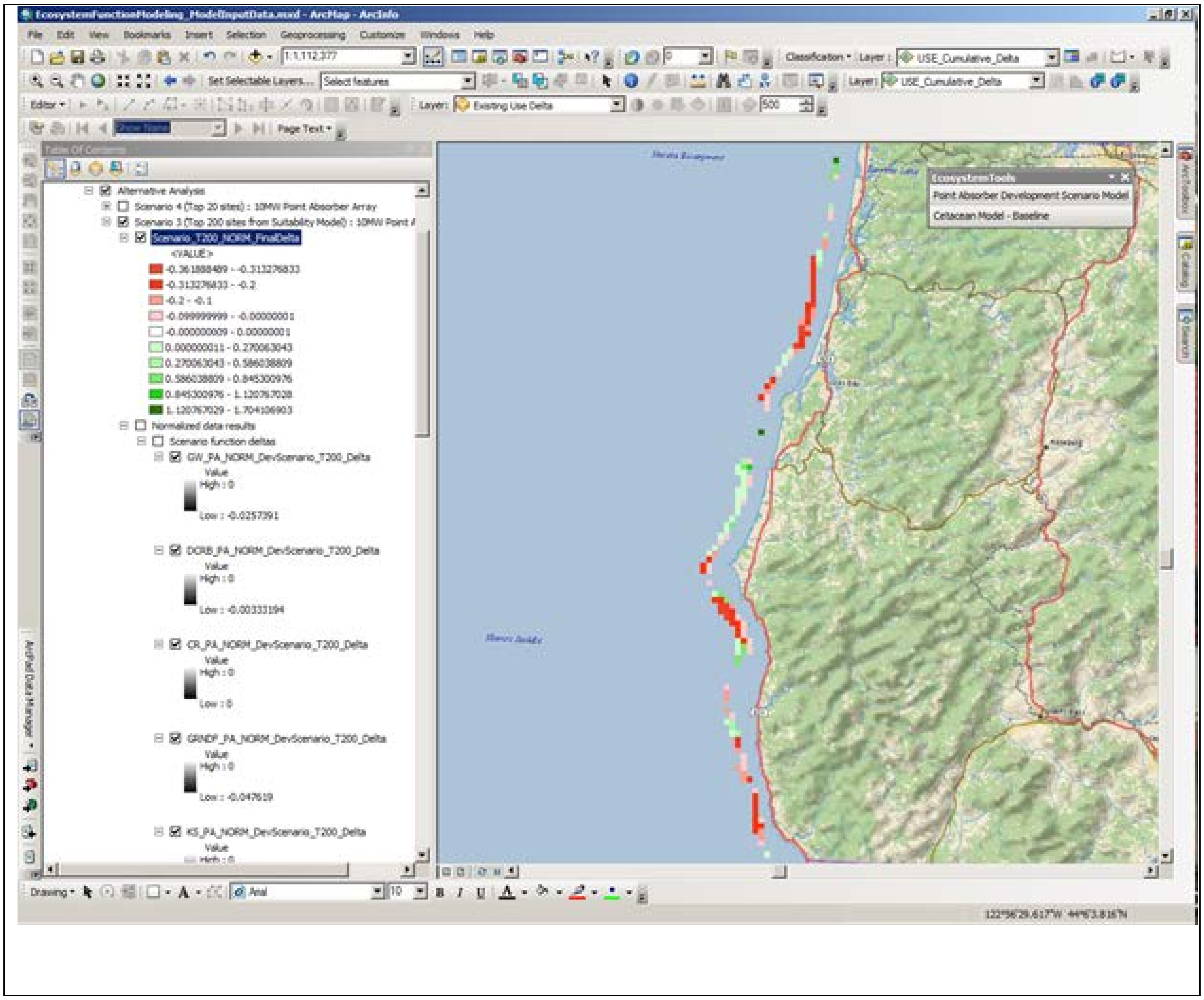


Figure 3. Screenshot of Cumulative Effects Framework in ArcGIS

2.6 FUNCTIONS AND ACTIVITIES

This section explains in greater detail two aspects of the model structure that determine model functions and activities: conceptual models and impact matrices.

2.6.1 Conceptual Models

The Framework currently includes a variety of conceptual models that define the relationship between ocean conditions and the ecological processes and human uses that rely on those conditions. Conceptual models define model specifications, or rather, define how data on attributes are scored to model the resource, ecosystem service, or function of interest. Attributes are indicators present within each map unit, and are measured in defined quantitative and/or qualitative ranges. In the conceptual models, each attribute is scored according to how it contributes to the performance of one or more functions. Functions are the physical and biological processes performed by ecosystems, and ecosystem services are the societal benefits that result from nature’s performance of functions.

For example, within the Coastal Wave Energy Device Feasibility Conceptual Model, the substrate attribute, defined as the dominant surface type within a one-nautical-mile-by-one-nautical-mile map unit, is classified as either “sand dominant,” “sand adjacent to rock,” “rock with sand secondary,” and “all other.” Each classification of substrate type is scored based on the ability of this type of substrate to support the anchoring of coastal wave energy devices, and support for renewable energy is one of the many ecosystem services that natural environments provide.

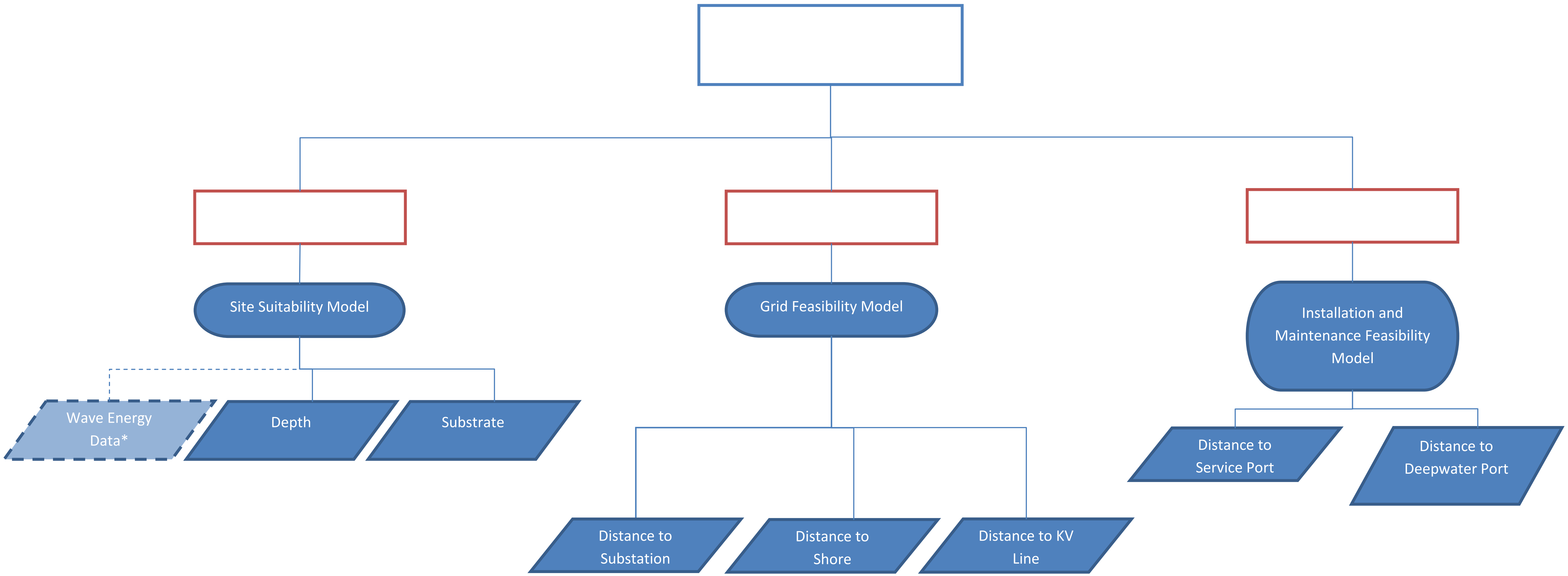
The resources, ecosystem services, and functions of interest were identified and vetted throughout various stakeholder engagement processes, including a Mini-Summit and three workshops. Detailed information on the Mini-Summit, First Workshop, Second Workshop, and Third Workshop can be found in Appendices A through D of this document.

These resources, ecosystem services, and functions of interest include:

- Coastal Wave Energy Device Feasibility in an Economically-Constrained Environment;
- Mid-Depth Wave Energy Device Feasibility in an Economically-Constrained Environment;
- Deep-Water Wave Energy Device Feasibility in an Economically-Constrained Environment;
- Cetacean Support;
- Ground Fishing Support;
- Kelp Support;
- Commercial Fishing Support;
- Non-Consumptive Recreation Support;
- Visual interaction; and
- Coastal Resilience.

The conceptual models and associated scoring criteria for eight of these resources, ecosystem services, and functions of interest follow. Conceptual models were not developed for either the Commercial Fishing Support or Non-Consumptive Recreation Support ecosystem services, since both of these services are currently mapped using a single data point. For example, the Commercial Fishing Support model relies solely on a data layer generated by FishCred, and the Non-Consumptive Recreation Support model relies solely on a data layer generated by EcoTrust/Surfrider Survey Data.

- Coastal Wave Energy Device Feasibility in an Economically-Constrained Environment (see Figure 4).
- Mid-Depth Wave Energy Device Feasibility in an Economically-Constrained Environment (see Figure 5).
- Deep-Water Wave Energy Device Feasibility in an Economically-Constrained Environment (see Figure 6).
- Cetacean Support (see Figure 7).
- Ground Fishing Support (see Figure 8).
- Kelp Support (see Figure 9).
- Visual interaction (see Figure 10).
- Coastal Resilience (see Figure 11).

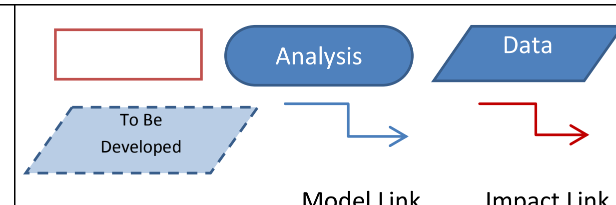


We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model: **Figure 4. Coastal Energy Production – Economically Constrained Environment**

Revision/Date: **1.8/Feb-2012**

Created By: **AR**



OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by:

Model Specifications

The economically-constrained coastal device feasibility model evaluates the feasibility of siting coastline converter and coastal surge devices in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection. The coastal device model combines three sub-models or functions to evaluate the feasibility of siting the device. Coastline converter devices are located on an existing natural or man-made coastline, or where a new coastline is artificially created in near-shore waters. Coastal surge devices harness the energy generated by a flap moving laterally in response to wave motion in shallow water. The three sub-models that determine coastal wave energy device feasibility include site quality, grid connection, and shore-side support.

The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for coastal device operation, and the presence of a substrate suitable for anchoring a coastal wave energy device. The grid connection sub-model evaluates the suitability of grid access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data
* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	0
2	10m < 20m	10
3	20m < 30m	0
4	30m < 40m	0
5	40m < 50 m	0
6	50m < 75m	0
7	75m < 85m	0
8	85m < 100m	0
9	100m < 200m	0
10	>200m	0

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	10
2	Shell	7
3	Gravel	7
4	Sand	8
5	Cobble	5
6	Mud	8

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data
*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).
Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

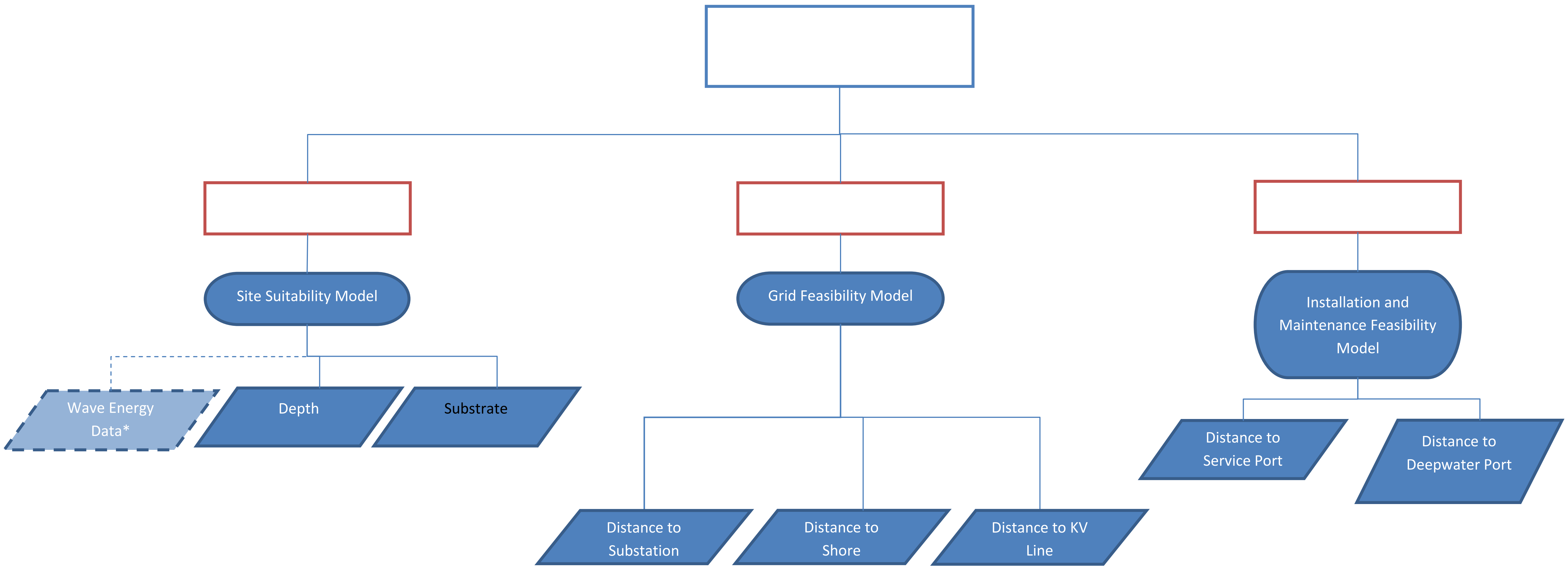
Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data



We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model: **Figure 5. Mid-Depth Energy Production - Economically Constrained Environment**

Revision/Date: **1.8/Feb-2012**

Created By: **AR**

Analysis

Data

To Be Developed

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by:

Model Specifications

The economically-constrained mid-depth wave energy device feasibility model evaluates the feasibility of siting offshore oscillating water column, offshore surge, offshore flywheel, and offshore pressure wave energy devices in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection. The mid-depth device model combines three sub-models or functions to evaluate the feasibility of siting the device.

The three sub-models that determine mid-depth wave energy device feasibility include site quality, grid connection, and shore-side support. The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for mid-depth device operation, and the presence of a substrate suitable for anchoring a mid-depth wave energy device. The grid connection sub-model evaluates the suitability of grid access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data

* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	1
2	10m < 20m	10
3	20m < 30m	9
4	30m < 40m	8
5	40m < 50 m	7
6	50m < 75m	4
7	75m < 85m	2
8	85m < 100m	1
9	100m < 200m	0
10	>200m	0

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	8
2	Shell	2
3	Gravel	10
4	Sand	2
5	Cobble	8
6	Mud	0

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data

*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).

Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

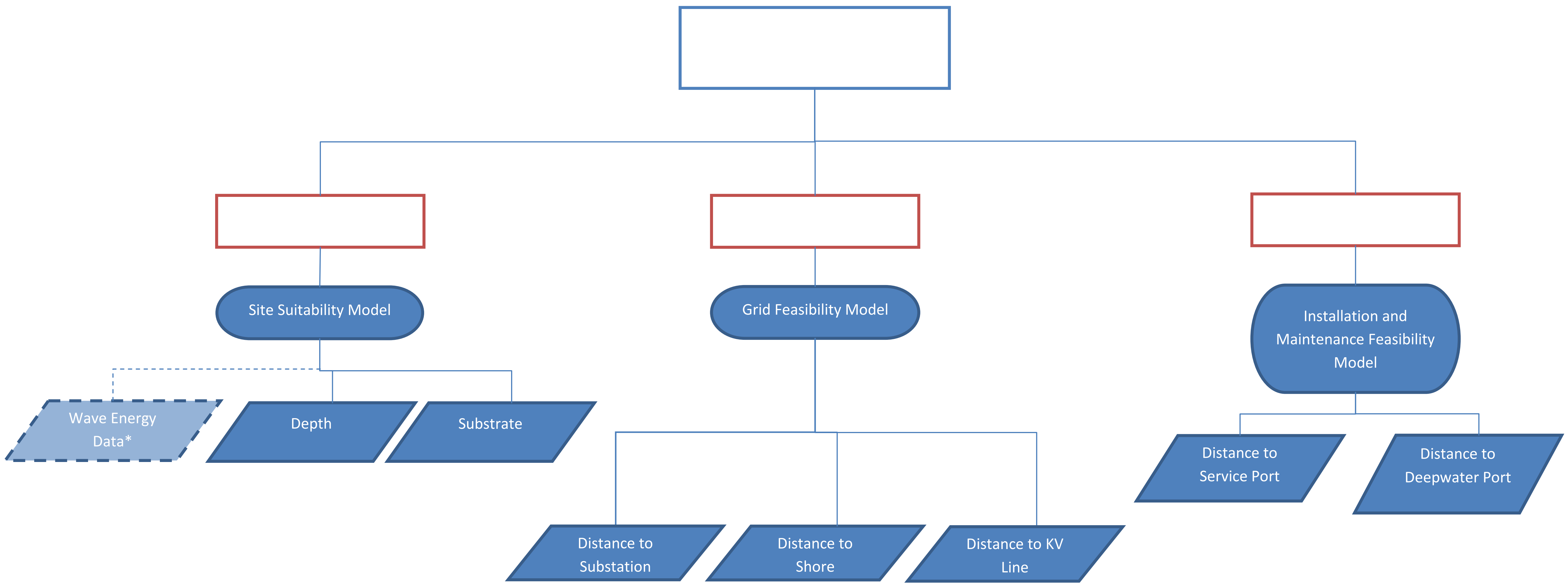
Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

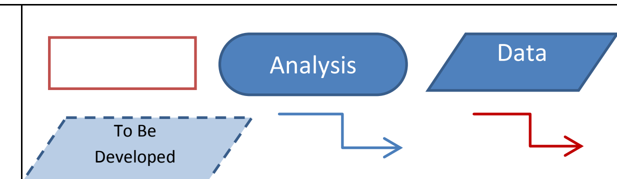
Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data



We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model:	**Figure 6. Deep-Water Energy Production – Economically Constrained Environment**	Legend	**Cumulative Effect Analysis Framework for Marine Renewable Energy**
Revision/Date:	**1.8/Feb-2012**		
Created By:	**AR**		**Developed by:**



Model Specifications

The economically-constrained deep-water wave energy device feasibility model evaluates the feasibility of siting offshore wave energy devices, such as point absorber and offshore attenuator/pivot devices, in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection.

The three sub-models that determine deep-water wave energy device feasibility include site quality, grid connection, and shore-side support.

The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for device operation, and the presence of a substrate suitable for anchoring deep-water wave energy devices. The grid connection sub-model evaluates the suitability of access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data
* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	0
2	10m < 20m	0
3	20m < 30m	0
4	30m < 40m	2
5	40m < 50 m	5
6	50m < 75m	10
7	75m < 85m	8
8	85m < 100m	4
9	100m < 200m	3
10	>200m	1

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	2
2	Shell	5
3	Gravel	5
4	Sand	10
5	Cobble	0
6	Mud	10

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data
*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).
Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data

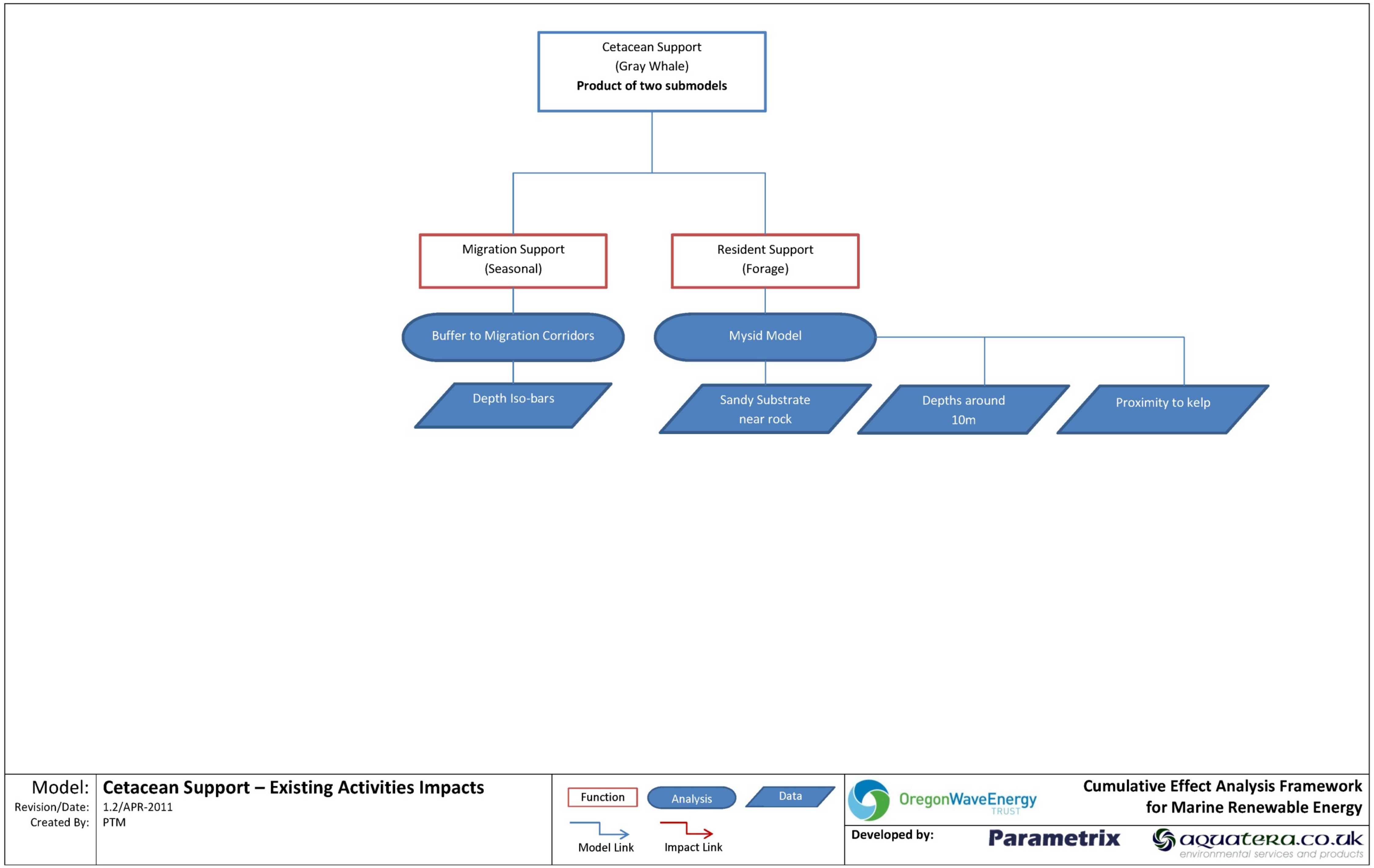


Figure 7. Cetacean Support – Existing Activities Impacts

Model Specifications

The cetacean support model includes two parts, migration support and foraging support. The model is Gray Whale specific (*Eschrichtius robustus*) and is a synthesis of both spatial and non-spatial data. The migration sub-function models corridors of importance based on observed point data and the correlation with physical environmental parameters, primarily depth contours. The forage sub-function is primarily for resident species and is also based on available observed data from the Oregon coast.

The impact models are the interaction of the function with known existing sea uses, conditions and activities. These are anthropogenic and include fishing effort, vessel navigation and water quality.

References:

Angliss, R. P. and B. M. Allen. 2007. Marine Mammal Stock Assessment Report: Gray Whale: Eastern North Pacific Stock. NOAA-TM-AFSC-193. http://www.nmfs.noaa.gov/pr/sars/species.htm Retrieved March 12, 2011.

Newell, Carrie 2010. Ecological Interrelationships Between Summer Resident Gray Whales (Eschrichtius robustus) and Their Prey, Mysid Shrimp (Holmesimysis sculpta and Neomysis rayi) along the Central Oregon Coast. MS Thesis. Oregon State University.

Ortega-Ortiz, Joel, Bruce Mate. 2008. Distribution and movement patterns of gray whales off central Oregon: Shore-based observations from Yaquina Head during the 2007/2008 migration. Report to Oregon Wave Energy Trust.

:

Attribute: Depth Iso-bars for Migration

Ref.	Classification	Score
1	< 10m	0.5
2	10m < 27.5m	3
3	27.5m < 32.5m	5
4	37.5m < 47.5m	10
5	47.5m < 60m	5
6	60m < 75m	3
7	> 75m	1

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Sand dominant	1.5
2	Sand adjacent to rock	5
3	Rock with sand secondary	3
4	All other	1

Source: DOGAMI

Attribute: Depths for Foraging

Ref.	Classification	Score
1	8m < 12m	5
2	Other	1

Source: 100m DEM Bathrymetry

Attribute: Proximity to Kelp

Ref.	Classification	Score
1	Within 100m of Survey	5
2	Other areas	1

Source: ODFW Survey Data processed

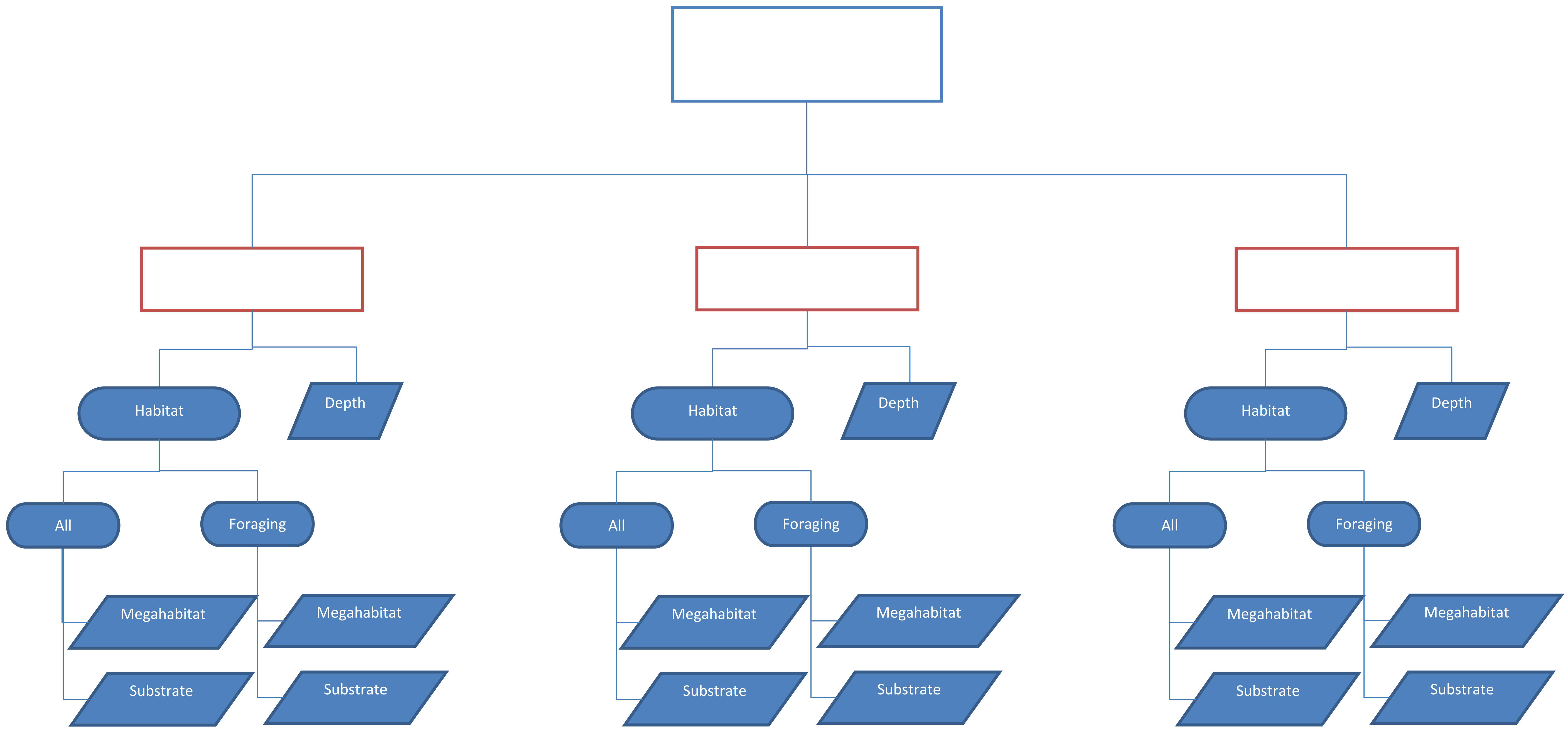
Attribute: Fishing Effort

Ref.	Classification	Score
1	<4m	10
2	4m < 5m	3.5
3	> 5m	0.01

Source: Interpolated NOAA Tidal Station Data

Notes on Certainty: Observed point validation.

Public Opinion: Level of importance and value based on feedback. Status and trends.



Model: **Figure 8. Groundfish Support**
Revision/Date: 1.2/APR-2011
Created By: PTM

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by:

Model Specifications

The groundfish support model contains three sub-models, which account for the unique habitat and foraging resources required throughout three life stages: egg/larvae, juvenile, and adult.

References:

Pacific Fishery Management Council, ESSENTIAL FISH HABITAT WEST COAST GROUNDFISH (Modified from: FINAL ENVIRONMENTAL ASSESSMENT/REGULATORY IMPACT REVIEW FOR AMENDMENT 11 TO THE PACIFIC COAST GROUNDFISH FISHERY MANAGEMENT PLAN, Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

Pacific Fishery Management Council, PACIFIC COAST GROUNDFISH FISHERY MANAGEMENT PLAN FOR THE CALIFORNIA, OREGON, AND WASHINGTON GROUNDFISH FISHERY AS AMENDED THROUGH AMENDMENT 19. July 2008.

Notes on Certainty: Observed point validation.
Public Opinion: Level of importance and value based on feedback. Status and trends.

Attribute: **Depth - Egg/Larval**

Ref	Classification		Score
1	0	150	10
2	151	274	7
3	275	549	0.01
4		≥550	0.01

Attribute: **Depth - Juv.**

Ref	Classification		Score
1	0	150	10
2	151	274	10
3	275	549	8
4		≥550	0.01

Attribute: **Depth - Ad.**

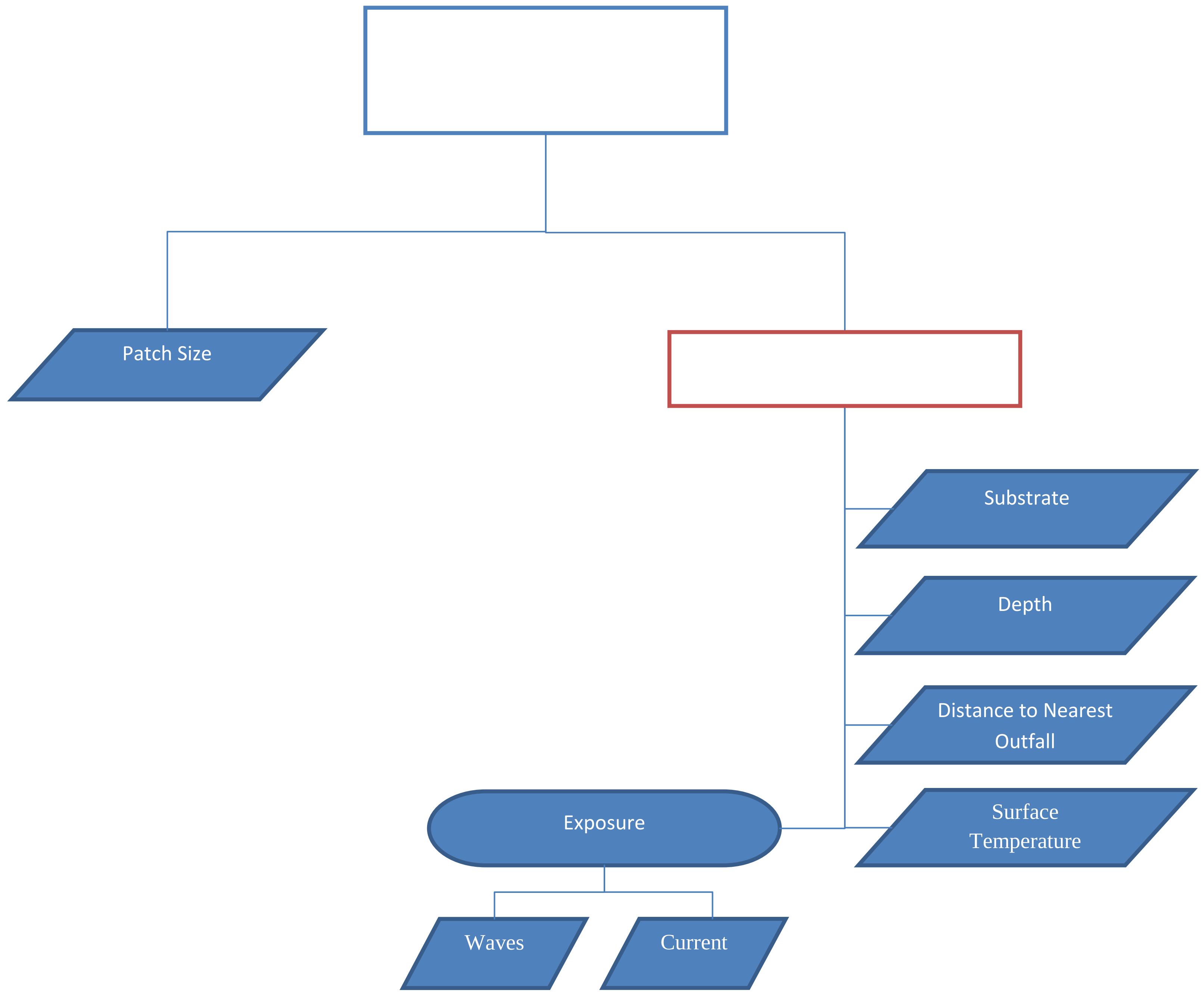
Ref	Classification		Score
1	0	150	10
2	151	274	10
3	275	549	10
4		≥550	0.01

Attribute: **Structure - Megahabitat**

Ref	*Classification*	All Adult Score	All Juv. Score	All Egg/Larvae Score
1	*BASIN*	8	7	6
2	CANYON_FLOOR	2	3	2
3	CANYON_WALL	2	3	2
4	CHANNEL	0.01	0.01	0.01
5	GULLY	0.01	0.01	0.01
6	MWZ	0.01	0.01	0.01
7	NEARSHORE	7	10	10
8	RIDGE	5	4	3
9	SHELF	10	7	4
10	SLOPE	2	3	2
11	Ter. Sea	5	5	5
	Unknown	1	1	1

Attribute: **Substrate**

Ref	Classification	All Score	Adult, Feeding Score	Juv, Feeding Score	Egg/Larvae Feeding Score
1	BOULDER	10	2	2	2
2	COBBLE	10	2	2	2
3	GRAVEL	5	2	2	2
4	GRAVEL/MUD	5	4	4	4
5	GRAVEL/ROCK	5	4	4	4
6	GRAVEL/SAND	4	7	7	7
7	MUD	5	7	7	7
8	MUD/ROCK	8	7	7	7
9	MUD/SAND	5	8	8	8
10	ROCK	5	2	10	10
11	ROCK/BOULDER	8	3	7	7
12	ROCK/GRAVEL	8	2	7	7
13	ROCK/MUD	8	4	8	8
14	ROCK/SAND	8	4	7	7
15	ROCK/SHELL	8	2	7	7
16	SAND	6	10	10	10
17	SAND/BOULDER	7	7	7	7
18	SAND/GRAVEL	6	7	7	7
19	SAND/MUD	7	8	8	8
20	SAND/ROCK	7	7	7	7
21	SAND/SHELL	5	7	7	7
22	SHELL	5	7	7	7
	Unknown	1	1	1	1



Model:	**Figure 9. Kelp Support**		**Cumulative Effect Analysis Framework for Marine Renewable Energy**
Revision/Date:	1.2/APR-2011		**Developed by:**
Created By:	PTM		

Model Specifications

The kelp support model includes two parts: patch size and a habitat sub-model. The habitat sub-model reflects observed requirements for kelp beds, including exposure, surface temperature, substrate, depth, and distance to nearest outfall.

References:

Davenport, A. C. Davenport and T. W. Anderson. 2007. Positive Indirect Effects of Reef Fishes on Kelp Performance: The Importance of Mesograzers. Ecology. Vol. 88, No. 6 (Jun., 2007), pp. 1548-1561.

Dayton, P. K., V. Currie, T. Gerrodette, B. D. Keller, R. Rosenthal and D. Ven Tresca. 1984. Patch Dynamics and Stability of Some California Kelp Communities. Ecological Monographs. Vol. 54, No. 3 (Sep., 1984), pp. 253-289.

Edwards, M. S. 2004. Estimating Scale-Dependency in Disturbance Impacts: El Niños and Giant Kelp Forests in the Northeast Pacific. Oecologia. Vol. 138, No. 3 (Feb., 2004), pp. 436-447.

Harold, C. and D. C. Reed. 1985. Food Availability, Sea Urchin Grazing, and Kelp Forest Community Structure. Ecology. Vol. 66, No. 4 (Aug., 1985), pp. 1160-1169.

Konar, B. and J. A. Estes. 2003. The Stability of Boundary Regions between Kelp Beds and Deforested Areas. Ecology. Vol. 84, No. 1 (Jan., 2003), pp. 174-185.

Mackey, Megan. 2006. Protecting Oregon's Bull Kelp. Pacific Marine Conservation Council.

Oregon Department of Fish and Wildlife. 2006. Oregon Nearshore Strategy. Marine Resources Program, 2040 SE Marine Science Drive, Newport, Oregon 97365, Web: www.dfw.state.or.us/MRP

Shaffer, J. Anne. 2000. Seasonal Variation in Understory Kelp Bed Habitats of the Strait of Juan de Fuca. Journal of Coastal Research. Vol. 16, No. 3 (Summer, 2000), pp. 768-775.

Notes on Certainty: Observed point validation.

Public Opinion: Level of importance and value based on feedback. Status and trends.

Attribute: Patch Size

Ref		Classification	Score
1	Low	0.01 - 224 ac.	2
2	Medium	224 - 447 ac.	5
3	High	< 447 ac.	10
4	Not Present		0.01

Attribute: Waves

Ref	Classification	Score
1	Low	8
2	Medium	10
3	High	2
4	Very High	1
5	N/A	1

Attribute: Tidal Range

Ref		Classification	Score
1	Low	1.06 - 1.44 ft.	8
2	Medium	1.44 - 1.83 ft.	10
3	High	> 1.83 ft.	2

Attribute: Substrate

Ref	Classification (Nearshore)	Score
1	BOULDER	10
2	COBBLE	6
3	GRAVEL	5
4	MUD	0.01
5	ROCK	8
6	SAND	0.01
7	SHELL	2
8	Unknown	1

Attribute: Depth

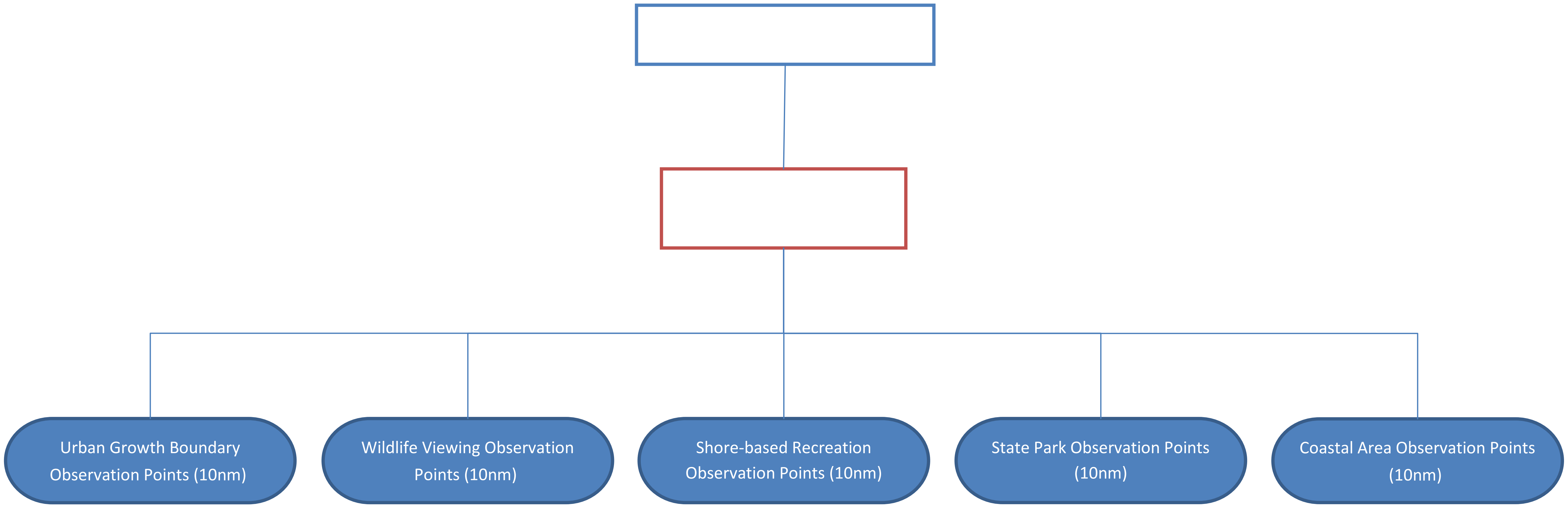
Ref	Classification	Score
1	≤ 15 m	10
2	15 - 20 m	10
3	20 - 25 m	8
4	25 - 30 m	6
5	30 - 35 m	4
6	35 - 40 m	2
7	> 40 m	0.01
8	Unknown	1

Attribute: Distance to Nearest Outfall

Ref		Classification	Score
1	Low	1 - 10 miles	1
2	Medium	10 - 20 miles	5
3	High	> 20 miles	10

Attribute: Surface Temperature

Ref		Classification	Score
1	Low	<9	5
2	Medium	9 - 10.1	10
3	High	> 10.1	1



Model:	**Figure 10. Visual Importance Function - Baseline**
Revision/Date:	1.1./Feb-2012
Created By:	PTM (JKo revised)

Analysis
Data

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by:

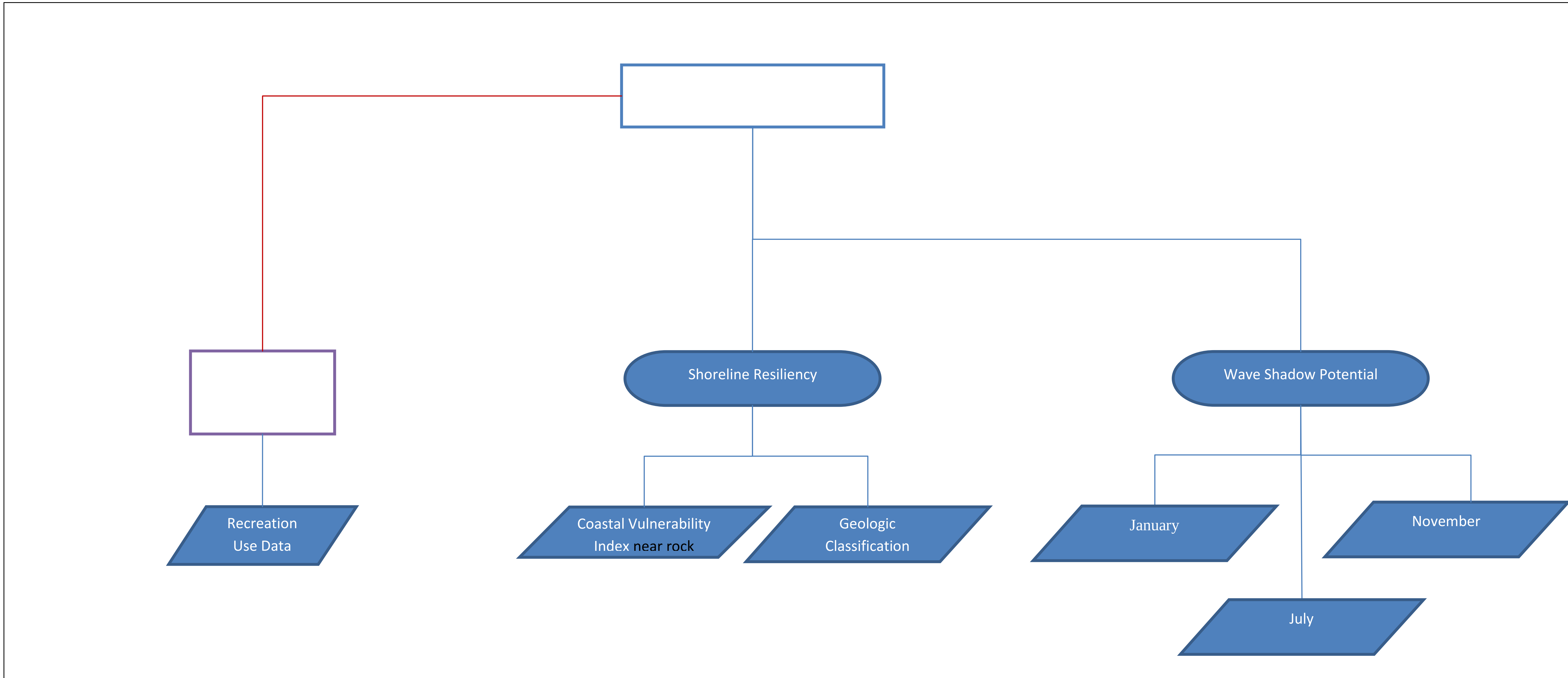
The economic values tied to tourism in Oregon coastal areas includes both passive/non-consumptive and active recreational activities (Oregon Coastal Management Program, 2008; Oregon State University, n.d.). Scenic viewing opportunities are non-consumptive recreational activities that are increasing in demand (Oregon Department of Parks and Recreation, 2003). It is, therefore, necessary to capture the visual component of each grid cell as it may be seen from points on the coastline. The Visual Importance Model is based the cumulative number of visible points that each grid cell can "see" along the coastline. Iterations of a viewshed model are conducted on each grid cell for each point type (cities and communities on the coast, park locations, and non-consumptive recreation areas) using a coastal elevation model to evaluate the possibility of the grid cells to "see" the points from the ocean. The output value for each grid cell is the sum of points that can be seen in all of the categories.

References:

Oregon Coast Management Program. (2008, May 23). *Oregon's Coastal Zone*. Retrieved December 16, 2009 from Oregon Coastal Management Program: http://www.oregon.gov/LCD/OCMP/CstZone__Intro.shtml

Oregon Department of Parks and Recreation. (2003, January). *Oregon Statewide Comprehensive Recreation Plan, 2003-2007*. Retrieved December 7, 2009 from Oregon Parks and Recreation Department: Planning : http://www.orgon.gov/OPRD/PLANS/SCORP.shtml

Oregon State University (n.d.). *Economies of the Oregon Coast*. Retrieved June09, 2009 from Oregon Wave Action Resource Education: http://ppgis.science.oregonstate.edu/?g=economies



Model:	**Figure 11. Coastal Resilience – Existing Activities Impacts**
Revision/Date:	2.0/MAY-2011
Created By:	JK

Analysis
Data

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by:

Model Specifications

Attribute: Coastal Vulnerability Index

Ref.	CVI Rank	Score
1	Very Low (1)	10
2	Low (2)	7
3	Moderate (3)	5
4	High (4)	2
5	Very High (5)	1

Source: NOAA

Attribute: Geologic Classification

Ref.	Rock Type 1	Rock Type 2	Score
1	Alkalic intrusive rock		8
2	Alluvial fan	Colluvium	2
3	Amphibolite		1
4	Amphibolite	Quartzite	1
5	Andesite	Basalt	10
6	Basalt		10
7	Basalt	Andesite	10x
8	Basalt	Mudstone	10
9	Basalt	Volcanic breccia	10x
10	Clay or mud	Silt	2x
11	Gabbro	Diabase	1x
12	Gabbro	Granitoid	1
13	Gravel	Terrace	4x
14	Graywacke	Mudstone	6x
15	Landslide		1
16	Mudstone	Graywacke	6
17	Mudstone	Sandstone	6
18	Mudstone	Siltstone	6x
19	Pelitic schist	Meta-basalt	10x
20	Peridotite	Serpentinite	1
21	Quartz diorite	Diorite	1
22	Sand		2x
23	Sand	Gravel	2x
24	Sandstone	Conglomerate	10x
25	Sandstone	Mudstone	6x
26	Sandstone	Siltstone	6x
27	Serpentinite	Basalt	10
28	Shale	Siltstone	6x
29	Siltstone	Sandstone	6x
30	Tholeiite	Alkaline basalt	10
31	Tonalite	Quartz diorite	1
32	Water/Ice		1

Source: DOGAMI

Attribute: Wave Shadow Potential (Nautical Miles from Shoreline)

Ref.	Classification	Score
1	0 - 1	0.6
2	1 - 4	0.002
3	> 4	1

Source: Parametrix

Attribute: Recreation Use

Ref.	Classification	Score
1	Used for Recreation	0.95
2	Not Used	1

Source: EcoTrust/Surfrider Survey Data

Coastal Resilience model is an estimate of the vulnerability of natural coastal resources to hazards resulting in erosion and inundation. Low scores are indicative of low relief, erodible substrates, history of subsidence and shoreline retreat, and high wave and tidal energy areas. For each grid cell, the model generates the mean value from its Shoreline Resilience and Wave Shadow Potential scores. The Shoreline Resiliency averages scores for Coastal Vulnerability Index and Geographic Classification. Coastal Vulnerability Index is a measure of the relative susceptibility of the coast to sea-level rise with classifications based on geomorphology, regional coastal slope, tide range, wave height, relative sea-level rise, and shoreline erosion and accretion rates (USGS 2001). The underlying geologic features provide by Oregon Department of Geology and Mineral Industries (DOGAMI) is scored relative to their vulnerability to erosion (i.e. harder rock classifications are least vulnerable to change, therefore receive highest scores. Wave Shadow Potential score for each grid is relative to predominant direction of wave action (currents) for the months of January, November, and July and its distance from shore. Grids greater than four nautical miles from shore have the least wave impact. Therefore, high Wave Shadow Potential (max. score = 1) will have little effect in the average with Shoreline Resilience score. Impacts relative to recreational activities will be developed at a later date and will reduce the Coastal Resilience score where appropriate.

Reference:

National Oceanic and Atmospheric Administration (NOAA). NOAA National Ocean Service Special Projects Division. NOAA's State of the Coast. Coastal Vulnerability to Sea-Level Rise. Source: USGS Woods Hole Science Center, http://pubs.usgs.gov/dds/dds68/htmldocs/data.htm

U.S. Geological Survey (USGS), Woods Hole Field Center. 2001. Coastal Vulnerability to Sea-Level Rise: A Preliminary Database for the U.S. Pacific Coast. Woods Hole, Massachusetts. Source: http://pubs.usgs.gov/dds/dds68/data/pacific/pacific.htm

Oregon Department of Geology and Mineral Industries (DOGAMI).

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2.6.2 Impact Matrices

The following table defines the impact scale of current conditions and siting and operating various wave energy devices on diverse marine functions and ecosystem services. Marine functions and ecosystem services that can be modeled in the existing Cumulative Effects model are marked with an asterisk.

- Atmospheric Cleansing
- Carbon Cycle Support
- Coastal Erosion/Storm Protection*
- Sediment Transport
- Crustacean Support*
- Cetacean Support*
- Groundfish Support*
- Kelp Support*
- Pinniped Support*
- Salmonid Support*
- Sea-bird Support*
- Human Population Support (Community)
- Nutrient Cycling
- Oxygen Production
- Primary Productivity
- Water Purification (Waste Processing)
- Employment
- Energy Production (Technical Suitability)*
- Fishing Support Recreation
- Vessel Transit Support (Fairways and Storm Shelter)*
- Viewsheds*

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Column2	Column3	Atmospheric Cleansing	Carbon Cycle Support	Coastal Erosion/Storm Protection	Sediment Transport	Crustacean Support	Cetacean Support	Groundfish Support	Kelp Support	Pinniped Support	Salmonid Support	Sea-bird Support	Human Population Support (Community)	Nutrient Cycling	Oxygen Production	Primary Productivity	Water Purification (Waste Processing)	Employment	Energy Production (Technical Suitability)	Fishing Support	Recreation	Vessel Transit Support (Fairways and Storm Shelter)	Viewsheds
Exisiting Situation	Fishing Support	0	-1	0	-1	-3	-1	-3	0	-1	-3	1	4	-1	0	0	-1	4	-4	0	0	-2	0
Exisiting Situation	Vessel Transit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exisiting Situation	Recreation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exisiting Situation	Water Purification (Waste and Spoils)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exisiting Situation	Cables (Existing and Wave Energy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exisiting Situation	Marine Designations (MPA/NWR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exisiting Situation	Composite score for existing uses only	0	-1	0	-1	-3	-1	-3	0	-1	-3	1	4	-1	0	0	-1	4	-4	0	0	-2	0
Scenario 1 - POINT ABSORBER	Composite Score device	0	0	0	0	-2	-1	-1	0	-1	-1	1	0	0	0	0	0	0	0	-2	-2	-2	-2
Scenario 1 - POINT ABSORBER	Composite score cables	0	0	0	0	0	0	-1	0	1	0	1	0	0	0	0	0	0	0	-2	-1	0	0
Scenario 1 - POINT ABSORBER	Composite score onshore	0	0	-1	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	-2	0	-2
Scenario 1 - POINT ABSORBER	Composite score for existing uses plus Scenar	0	-1	-1	-1	-3	-1	-3	0	-1	-3	1	4	-1	0	0	-1	4	-4	-2	-2	-2	-2
Scenario 2 - OSCILATING WAVE SURVE CONVERTER	Composite Score device	0	0	1	-1	1	-3	-1	-2	-3	-2	-2	0	0	0	0	0	0	0	-1	-2	-1	-3
Scenario 2 - OSCILATING WAVE SURVE CONVERTER	Composite score cables	0	0	-2	0	-1	-3	-1	-2	-3	0	-1	0	0	0	0	0	0	0	-2	-1	0	-1
Scenario 2 - OSCILATING WAVE SURVE CONVERTER	Composite score onshore	0	0	-2	0	0	0	0	0	-1	0	-2	0	0	0	0	0	0	0	0	-2	0	-2
Scenario 2 - OSCILATING WAVE SURVE CONVERTER	Composite score for existing uses plus Scenar	0	-1	-2	-1	-3	-3	-3	-2	-3	-3	-2	4	-1	0	0	-1	4	-4	-2	-2	-2	-3
Scenario 3 - 10MW POINT ABSORBER ARRAY	Composite Score device	0	0	0	-1	-3	-3	-2	0	-1	-1	2	0	0	0	0	0	0	0	-3	-2	-3	-2
Scenario 3 - 10MW POINT ABSORBER ARRAY	Composite score cables	0	0	0	0	0	-3	-2	0	-1	0	2	0	0	0	0	0	0	0	-3	-2	-1	0
Scenario 3 - 10MW POINT ABSORBER ARRAY	Composite score onshore	0	0	-1	0	0	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	-2	0	-2
Scenario 3 - 10MW POINT ABSORBER ARRAY	Composite score for existing uses plus Scenar	0	-1	-1	-1	-3	-3	-3	0	-1	-3	2	4	-1	0	0	-1	4	-4	-3	-2	-3	-2
Scenario 4 - 10MW OSCILATING WAVE SURVE CONVERTER	Composite Score device	0	0	2	-3	2	-3	-1	-2	-3	-2	-2	0	-1	0	0	0	0	0	-3	-2	-2	-3
Scenario 4 - 10MW OSCILATING WAVE SURVE CONVERTER	Composite score cables	0	0	0	0	0	-3	-1	-2	-3	-1	-2	0	0	0	0	0	0	0	-3	-2	0	-3
Scenario 4 - 10MW OSCILATING WAVE SURVE CONVERTER	Composite score onshore	0	0	-3	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	-2	0	-2
Scenario 4 - 10MW OSCILATING WAVE SURVE CONVERTER	Composite score for existing uses plus Sceanr	0	-1	-2	-3	-2	-3	-3	-2	-3	-3	-2	4	-1	0	0	-1	4	-4	-3	-2	-2	-3

Figure 12. Impact Matrix (Draft)

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3. INFORMING THE TERRITORIAL SEA PLANNING PROCESS

3.1 INTRODUCTION

Part Five of the Oregon TSP requires the state "to conserve marine resources and ecological functions for the purpose of providing long-term ecological, economic, and social value and benefits to future generations." Further, Part Five of the TSP provides a loose framework for making decisions concerning the development of renewable energy facilities (e.g., wind, wave, current, thermal, etc.) in the Territorial Sea and specifies the areas where that development may be sited.[1]

While the Framework was initially designed in-part to support ongoing efforts to zone Oregon's Territorial Sea, ongoing involvement with the TSP process has revealed that at this point, there is no mechanism for integrating the Framework into the planning process. In part, this change was driven by the actions of the OPAC, which is responsible for reviewing and recommending amendments to the TSP under ORS 196.443. As previously stated, it became apparent in fall 2011, when DLCD staff introduced the *TSP Resource Protection Criteria and Planning Options for Siting Marine Renewable Energy Development* report, that the Framework could not be integrated into the TSP amendment process for the following reasons:

- DLCD's definition that all existing uses in the TSP are sustainable. DLCD maintains that existing uses of the Territorial Sea are sustainable, thus within this worldview, cumulative effects could only occur with the introduction of additional ocean uses (i.e., wave energy development).
- Lack of consensus on the appropriate methodologies to delineate Goal 19 resources. Led by the Council on Environmental Quality, the Interagency Ocean Policy Task Force developed best practices for CMSP[2]. These recommendations establish high-level direction and policy guidance; one of the key recommendations was to adopt ecosystem-based management as a foundational principle for the comprehensive management of the ocean, coasts, and Great Lakes. The ecosystem services-based structure used by the project team to develop the Framework is consistent with this recommendation. Further, the methodologies used by OPAC stakeholders to delineate "Level 1" vs. "Level 2" resources do not often involve measurement and modeling of landscape attributes to determine the ability of a spatially-explicit area within the Territorial Sea to support the resource of interest. That is, the designation of Level 1 and Level 2 resources is often determined by methodologies that do not utilize an ecosystem services-based structure. Thus, this disagreement on the preferential method of data collection, data management, and mapping protocols creates challenges, given the lack of consensus on the knowledge needed to inform and improve policy decisions.
- OWET is not a member of the OPAC and its TSP Workgroup. OWET, and other representatives from the wave energy industry and stakeholder groups, rely on public

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[1] Additional information on the TSP may be accessed at the Oregon.gov Oregon Coastal Management Program website. Available online at: <http://www.oregon.gov/LCD/OCMP/Ocean_TSP.shtml>. Accessed on February 22, 2012.

[2] White House Council on Environmental Quality. Final Recommendations of the Interagency Ocean Policy Task Force. July 19, 2010. Available online at: <http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf>. Accessed on February 21, 2012.

comment to share perspectives and concerns regarding the ongoing TSP process. As a result, OWET has limited ability to recommend and integrate protocols for evaluating existing, alternative, and future ocean uses into the TSP.

- Insufficient time to vet the results of the Framework with wave energy industry representatives. At the time that the *TSP Resource Protection Criteria and Planning Options for Siting Marine Renewable Energy Development* report and its recommendations were developed, there was insufficient time to apply the Framework, and definitively determine whether the results of the Framework created greater or lesser opportunities for wave energy development.

While the Framework is not currently being integrated into the TSP process, the Framework currently provides an unparalleled approach to evaluating the tradeoffs associated with coastal and marine spatial planning, and is one of the formative building blocks of the BASS Tool being developed to assist the DOE, the NOAA, and the BOEM to make responsible CMSP decisions. For additional information on how the Framework is shaping parallel CMSP processes, please see Chapter 3: Updating, Refining, and Increasing the Use of OWET Cumulative Effects Framework.

3.2 WAVE ENERGY DEVICE FEASIBILITY

The MarineMap Consortium, DLCD, Oregon Department of Fish and Wildlife, and OWET have all contributed to the development of data for MarineMap, a web-based tool designed to support the TSP process. MarineMap provides spatially-explicit information on the many uses and values the Territorial Sea supports: fishing, shipping, recreation, and others. While MarineMap will not help decision makers understand the complex interaction of economic, social, and environmental impacts associated with wave energy facility development and operation, it is easy to access and use. In other words, MarineMap enables users to quickly identify the areas of the Territorial Sea that support or are capable of supporting diverse marine uses and values, without providing a mechanism of evaluating the trade-offs between alternative uses and values.

To support OWET's Industry Advisory Group, Parametrix and Aquatera developed a series of mapping products, integral components to the Framework and also MarineMap data layers, to inform the TSP process. To accomplish this, the team combined existing information on wave energy device types, interviews with inventor and developer representatives, and experiences from international development. These inputs informed a database of device suitability parameters used to develop and map spatially explicit device suitability areas. These areas represent a broad set of developer and technology perspectives and a range of device suitability.

The objectives of this effort and the key findings of this initiative are summarized in a Technical Memorandum that is included as Appendix E of this report. A summary of the industry representatives engaged in the development of wave energy feasibility model parameters and scoring criteria is included as Appendix F of this report.

4. CONCLUSION

Phase 2 provided considerable refinement and evolution of the Framework. This process will need to continue as the Framework is used in new contexts and as Marine Spatial Planning processes and wave energy development evolve. The anticipated next steps that have been identified to address this need include the following:

4.1 UPDATING, REFINING, AND INCREASING THE USE OF OWET'S CUMULATIVE EFFECTS FRAMEWORK

Discrete next steps have been identified to update, refine, and increase the use of the Framework for evaluating the impacts and issues associated with wave energy development. Phase III of the Cumulative Effects Framework development will include three key tasks: 1) completion of a case study, 2) creation of new and improved data sources, and 3) continued stakeholder engagement.

4.1.1 Completion of a Case Study

The Cumulative Effects Framework has always been designed to help decision makers understand the potential economic, social, and environmental impacts associated with wave energy facility development and operation. The development of this tool has required evaluation and integration of hundreds of data sets, been vetted with partner agencies and wave energy industry representatives, and has been shaped though outreach and an effort to inform public policy.

The next phase of Framework development will require completing a case study to test the framework based on a given scenario, and use the results of the modeling analysis to identify areas within the Territorial Sea that, if developed for wave energy, would result in the greatest change and/or generate the most impact. This case study is critical to testing the Framework's ability to assist wave energy developers in making better choices for siting and operating wave energy facility development and operation.

4.1.2 Creation of New and Improved Data Sources

To improve how cumulative impacts are measured and modeled over time, Phase III will focus on reconciling spatial scales of existing data layers, and continuing to improve upon the current data catalogue, as described in greater detail below.

4.1.3 Reconciling Spatial Scales

In Phase I and throughout half of Phase II, the goal of the Framework was to evaluate the cumulative effects of siting wave energy devices within an area 100 miles offshore from the Oregon Coast. As a result, to ensure the cost-effective development of the Framework, a grid cell size of 1 nautical mile by 1 nautical mile was selected as the common unit of measurement and model output for all resources. However, to inform the TSP process, the unit of measurement for mapping wave energy device suitability was more recently completed at the 10-meter-by-10-meter grid cell size to allow for a detailed, meaningful assessment of suitability within the Territorial Sea.

4.1.4 Updating Data Sets and Creating Additional Data Sets

As new data becomes available, the Framework's data catalogue will be updated and revised. Information relevant to data accuracy and uncertainty will be used to improve the reliability and applicability of conceptual models for the many uses and values the marine environment supports, including fishing, recreation, and others.

In addition, spatially-explicit wave energy device suitability information is a key component of the Framework and a necessary tool for integrating stakeholder values and concerns across a range of resources and user groups. As needed, OWET will continue to develop and refine wave energy device suitability models to ensure that the best data and resources are integrated into the Framework, with the goal of supporting better decision-making to advance the responsible development of wave energy.

4.2 STAKEHOLDER ENGAGEMENT

Continuing efforts to engage stakeholders will include additional workshops and the expansion of focus groups to focus Framework development and to ensure the best data and resources are integrated into the model.

APPENDIX A

Mini-Summit Summary and Attendees List

MINI-SUMMIT SUMMARY AND ATTENDEES LIST

INTRODUCTION

On September 27, 2011 Parametrix hosted a stakeholder outreach coordination meeting in Portland, Oregon. The objective of the meeting, or mini-summit, was to review Phase I of the Cumulative Effects Framework development; discuss plans to continue to develop the Framework in Phase II; and discuss goals, needs, and concerns of industry that should be used to tailor future efforts to develop the Framework. A list of attendees and a copy of the meeting agenda follows.

Attendees of the Mini-Summit included:

Attendee	Affiliation
Paul Klarin	Department of Land and Conservation
Tanya Haddad	Department of Land and Conservation
Reenst Lesemann	Columbia Power Technologies
John Fedorko	Aquamarine Power
Mark Eckenrode	Bureau of Ocean Energy Management
Bob Eder	Fisherman Involved in Natural Energy
Nick Furman	Oregon Dungeness Crab Commission
Onno Husing	Oregon Coastal Zone Management Association
Bridgette Lohrman	National Oceanic and Atmospheric Administration
Kaety Hildenbrand	Oregon State University
Steven Brandt	Oregon Sea Grant

Cumulative Effects Analysis Framework

Stakeholder Outreach Coordination Meeting

DoubleTree Lloyd District, Presidential Suite
1000 NE Multnomah Street
Portland, Oregon

Agenda

6:30 Welcome and Introductions

Review of Phase One of Cumulative Effects Analysis Project

Phase Two for Cumulative Effects and Other Siting and Planning Tool Efforts

Discussion on Goals, Needs and Concerns for Phase Two

8:30 Reflections

Dinner to be served – Please share any dietary restrictions or concerns.

For more information or questions, contact:

Paul Manson
Parametrix
503-516-6056 (ofc)
503-804-1645 (mobile)

APPENDIX B

First Workshop Summary and Attendees List

FIRST WORKSHOP SUMMARY AND ATTENDEES LIST

On November 4, 2011, Ann Radil and Kevin Halsey of Parametrix, and Jason Busch, the Executive Director of OWET, met with Rick Williams of SAIC and David Gibson of Oregon Iron Works to review draft wave energy device feasibility model results; vet landscape attributes and associated suitability scoring; and discuss how the wave energy device feasibility model results could be used to inform the TSP process.

Feedback from SAIC and Oregon Iron Works representatives was used to modify the grid connection sub-model of the coastal, mid-depth, and deep-water feasibility models, to improve the accuracy of model output in an economically-constrained, or pre-commercial context.

APPENDIX C

Second Workshop Summary and Attendees List

SECOND WORKSHOP SUMMARY AND ATTENDEES LIST

On December 20th, Ann Radil and Kevin Halsey of Parametrix, and Jason Busch, the Executive Director of OWET, provided a webinar to educate Bob Lurie and George Wolff of Ocean Power Technologies (OPT) on efforts-to-date to develop the Cumulative Effects Framework, focusing specifically on providing an overview of the research and development that led to the development of the wave energy device feasibility conceptual models and model algorithms.

Specifically, Parametrix, OWET and OPT staff discussed the draft wave energy device feasibility model results; compared the scoring of the wave energy device feasibility models across four sited previously (and by other methodologies) identified by OPT as preferred locations for wave energy development; vet landscape attributes and suitability scoring used to determine wave energy device feasibility in an economically-constrained environment; and discussed how the wave energy device feasibility model results could be used to inform the TSP process.

Feedback garnered during the second workshop with OPT was used to modify the grid connection sub-model of the coastal, mid-depth, and deep-water feasibility models, to improve the accuracy of model output in an economically-constrained, or pre-commercial context.

APPENDIX D

Third Workshop Summary and Attendees List

THIRD WORKSHOP SUMMARY AND ATTENDEES LIST

On February 3, 2012, Ann Radil of Parametrix provided a webinar to OWET Board Members to discuss efforts-to-date to develop the wave energy device feasibility models. The objectives of the webinar were as follows:

- To review the components of the Cumulative Effects Framework, including wave energy device feasibility and other marine resource use and support models.
- To review the Framework's functionality at relating environmental, economic, and social interactions with current and alternative ocean conditions and uses.
- Discuss what the capabilities and limitations of the wave energy feasibility model results, and how these capabilities and limitations can be effectively communicated to TSP stakeholders.

APPENDIX E

Industry Area Mapping for TSP

TECHNICAL MEMORANDUM

Date:	January 9, 2012
To:	Jason Busch, OWET
From:	Paul Manson, Parametrix; Kevin Halsey, Parametrix; Ann Radil, Parametrix
Subject:	Industry Area Mapping for TSP Process
cc:	Gareth Davies, Aquatera, Ltd
Project Number:	283-6309-001 (01/02)
Project Name:	Cumulative Effects Phase II

INTRODUCTION

To support the Oregon Wave Energy Trust's (OWET's) Industry Advisory Group (IAG), Parametrix and Aquatera were asked to develop a series of mapping products to inform the Territorial Sea Plan (TSP) process. To accomplish this, the team combined existing information on wave energy device types, interviews with inventor and developer representatives, and experiences from international development. These inputs informed a database of device suitability parameters used to develop and map spatially explicit device suitability areas. These areas represent a broad set of developer and technology perspectives and a range of device suitability.

In addition to demonstrating where it is technically feasible to site wave energy devices, Parametrix developed a sub-set of device suitability parameters to model the feasibility of siting wave energy devices in an economically-constrained environment. Relative to the parameters used to model technical feasibility for siting wave energy devices, the economically-constrained parameters further limit the feasibility of siting wave energy devices based on proximity to the electrical grid. The goal is to provide the Department of Land Conservation and Development (DLCD) with a final data product that can be integrated into Marine Map for use in the TSP process in 2012. The agency intends to develop a series of management scenarios for the Part 5 amendment, and the suitability areas are needed to encourage the designation of areas in the territorial sea that will have a better chance of meeting tangible device and development requirements. The economically-constrained wave energy device suitability models are currently being used for this process, since these models better represent the current challenges and opportunities facing wave energy project developers.

KEY FINDINGS

The technology types incorporated in the models included attenuators, point absorbers, surge, coastal wave generation, and mid-depth pressure plate-type devices. These devices are seen as representing the core device types anticipated to be commercially viable in Oregon. Suitability criteria were also collected for wind, oscillating water column, and flywheel devices. Device suitability model results are driven entirely by engineering and technical criteria, and therefore reflect practical assumptions of economic viability based on cabling, anchoring, access to deep water and service ports, and proximity to transmission lines and substations. Some results identify areas suitable for wave energy that, if developed, may create conflict with existing uses; this is addressed in a later section of this memo.

Wave energy device suitability was modeled for Oregon's territorial waters, as well as a portion of the outer continental shelf (OCS). The project area is defined as the Region 50 nautical miles (nm) offshore the coast of Oregon, and is 2,131 nm^2. The results of the modeling effort are delineated using "natural breaks". This classification of model results is based upon interpretation of the histogram of data variables and is used to identify the areas that are best suited to coastal, mid-depth, and offshore wave energy devices, given the aforementioned technical and economic parameters.

Coastal, mid-depth, and offshore wave energy device suitability was interpreted by identifying "natural breaks" in the frequency distribution histogram of the model results. Histograms have long been used to evaluate data and patterns. For this evaluation, a histogram was created for each technology class to illustrate the frequency of wave energy device suitability score for each raster grid cell included in the study area. Thus, the histograms for each technology class illustrate the general shape and spread of suitability model results.

There are a number of reasons why categorizing wave energy device suitability using the natural breaks methodology is superior to calculating "hard breaks" in the data, such as the top 1 percent of all model results, the top 2 percent of all model results, etc. These benefits are best understood in light of the goal of this assessment, which is to inform the TSP process. By identifying natural breaks in the datasets, it is possible to consider a suite of alternative development scenarios, without excluding from consideration areas with marginally inferior conditions. Using hard breaks to identify areas suitable for wave energy development would result in distinguishing areas suitable for wave energy development from areas unsuitable for wave energy development based on minor modeling differences that are within the margin of error of the datasets, thus introducing the possibility of making planning decisions using erroneous data.

While it is not recommended that hard breaks are used for planning purposes, it is nonetheless useful to have a context for evaluating the areal extent of the territorial sea and OCS suitable for developing coastal, mid-depth, and offshore wave energy devices. The top 5 percent most suitable coastal wave energy device model results cover an area of 6 nm^2; the top 5 percent most suitable mid-depth wave energy device model results cover an area of 29 nm^2; and the top 5 percent of the most suitable offshore wave energy device model results cover an area of 39 nm^2. Thus, based on the top 5 percent of all suitability model results, in an economically-constrained environment, 74 nm^2 off the coast of Oregon are suitable for wave energy development, and this area is located entirely within the territorial sea.

DESIGNATION OF AREAS SUITABLE FOR WAVE ENERGY DEVELOPMENT

The coastal, mid-depth, and offshore model results indicate that in general, there are discrete areas suitable for multiple wave energy device types along the Oregon coast. These "hot spots" of wave energy development are described in the following section.

Beginning at the Washington/Oregon border and moving south, the first area suitable for wave energy devices is located south of the Columbia River and north of Tillamook Head. This area is characterized by a gently sloping and sandy seafloor and is suitable for coastal, mid-depth, and offshore wave energy devices. While access to Astoria's port is favorable, transit around the jetties adds substantial traveling distances to and from proximal wave energy devices. This area has been identified by the Northwest National Marine Renewable Energy Center (NNMREC) as a potential location for their test birth facility.

Some coastal and mid-water type devices are well-suited to conditions found in the Tillamook and Netarts Bay area. These areas show potential primarily due to possible access opportunities out of Tillamook/Garibaldi and favorable device depths near shore. Ocean Power Technologies (OPT) has proposed consideration of a 41-square-mile area off Tillamook Head for wave energy development.

The next area suitable for multiple wave energy device classifications is located in an approximately 12-mile-long region located offshore of Newport. Coastal and mid-depth devices are best suited to this site; however, all wave energy device types can be supported here due to favorable port access, close proximity to grid connections, and good anchoring potential. OPT and NNMREC have identified an approximately 35-square-mile area off the coast of Oregon as targeted zones for wave energy development and siting of the test berth facility, respectively.

Moving south, the next hot spot is located off the coast of Florence. This area is approximately 10 miles long and encompasses conditions favorable for the development of coastal and offshore wave energy devices, and to a lesser extent, mid-depth devices. OPT has identified this area as a desirable location for wave energy development.

The next substantial area suitable for wave energy development is located offshore of Reedsport. This location is favorable for the development of coastal, mid-depth, and offshore wave energy device types. Further, this area contains the top 37 percent of all coastal wave energy device suitability model results, the top 12 percent of all mid-depth device suitability model results, and the top 1 percent of all offshore wave energy device suitability model results. While suitability for coastal and mid-depth devices is roughly centered 5 miles north and south of Reedsport, the siting of offshore devices continues to be favorable for approximately 10 miles south of Reedsport, tapering off towards Coos Bay. Both OPT and NNMREC have identified adjacent and overlapping areas in this vicinity as potential sites for siting wave energy devices. The wave suitability models indicate that the offshore environment between Reedsport and Coos Bay is best suited to mid-depth and offshore devices.

Approximately 5 miles south of Coos Bay, offshore of Bandon, there are favorable conditions for coastal, mid-depth and offshore wave energy device types. While depths limit coastal and mid-depth device placement to a narrow band, this area appears to provide extensive opportunity for offshore devices, such as point absorbers and point attenuators. Neither OPT nor NNMREC have proposed this location for wave energy development.

There are extensive, favorable opportunities to develop wave energy devices off the coast of Port Orford. Specifically, a 10-mile band off the coast of Port Orford contains some of the best opportunities for developing all three classifications of marine energy devices, including the top 11 percent and top 1 percent of model results for coastal wave energy devices and offshore wave energy devices, respectively. Neither OPT nor NNMREC have proposed this location for wave energy development. Currently, the data available to populate the wave energy device suitability models does not capture the possible interaction of many offshore islands and rock formations that may alter the wave regime in this region. As a result, this area requires further study.

Last, the area offshore of Brookings also contains favorable conditions for supporting coastal, mid-depth, and offshore wave energy devices. This area appears especially favorable for the siting and operation of offshore wave energy device types. However, as previously stated, the wave regime in this region may be altered by proximal islands and rock formations, and as a result, the suitability of siting and operating wave energy devices in this area requires additional study.

CONSTRAINTS ON DEVELOPING WAVE ENERGY RESOURCES

Designation of areas suitable for wave energy development is a difficult task requiring careful consideration of environmental, socioeconomic, and regulatory constraints. The wave energy suitability models utilized in this analysis focus on the technological and economic constraints associated with developing a wave energy site. Thus, additional consideration of potential interactions with existing marine uses or natural resource values is required, and integrating these constraints will reduce the extent of areas suitable for wave energy development. An analysis is currently being conducted to identify environmentally-sensitive habitats, which will provide greater specificity on Goal 19 resources. Initial results indicate that the areas suitable for wave energy development that create the least conflict with existing uses are located near Reedsport. The area offshore of Newport may have greater conflict with existing uses, including commercial fishing and recreation. Developing wave energy in the opportunity zone located between the Columbia River estuary and Tillamook Head could disrupt existing recreation uses; however, developing this area for wave energy would result in relatively fewer visual, environmental, and fishing impacts.

METHODOLOGY AND ASSUMPTIONS

The modeling uses a spatial multiple criteria decision analysis (MCDA) method. The goal of an MCDA is to identify the key parameters or variables that influence siting decisions for wave energy and combine spatially-explicit criteria to identify desirable areas for wave energy development. A geospatial information system (GIS) and a database with the MCDA parameters compute the spatial solutions based on input from users. The parameters are combined using a weighted product model with all parameters currently weighted equally. The parameters used to model coastal, mid-depth, and offshore wave energy device suitability include:

- Water depth.
- Substrate type.
- Distance from the nearest substation.
- Distance to shore.
- Distance to the nearest transmission cable.
- Distance to service port.
- Distance to deep water port (for device installation).

Technology Suitability

Different classes of wave energy devices require unique conditions to generate and transmit electricity. The wave energy suitability models contained in this analysis include a range of wave energy device types:

- Coastline Converters: Located on an existing natural or manmade coastline, or where a new coastline is artificially created in near-shore waters.
- Coastal Surge Devices: Where a flap moves laterally in response to wave motion in shallow water (less than 20 meters).
- Offshore Point Absorbers: Where the water moves a float vertically.
- Offshore Oscillating Water Columns: Where the surge generated by waves within a chamber is used to drive air through an above-surface turbine.
- Offshore Surge Devices: Where the pressure differential between two closely situated flaps is used.
- Offshore Attenuator/Pivots: Where the articulation of a joint around a pivot is converted into compressive or rotational energy.
- Offshore Flywheel Devices: Where the motion induced by passing waves is transformed into rotational energy that accelerates a flywheel or gyroscope.
- Offshore Pressure Devices: Seabed-based flexible reservoirs of air which become cyclically compressed and expanded as a wave peak and trough pass over.

To effectively generate and transmit electricity, wave energy devices require the following types of supporting infrastructure:

- Offshore Cable Connection Hub: A seabed-fixed or floating structure, above or subsurface, where multiple cables are connected together, possibly with voltage step-up and/or AC to DC conversion.
- Offshore Transmission Cables: AC or DC cables that transfer electricity over larger distances offshore through cables, or onshore through buried cables or overhead wires.
- Beach Landfall: Section of coast where cables cross from sea to land by being buried into a trench across the shore.
- Directional Drilling Sites: Where a borehole is drilled through and cables can be pulled to make the transition from sea to land.

Suitability Criteria

The suitability of a given area for a particular class of wave energy devices is determined based on the potential site's presence or absence of criteria necessary for wave energy development and operation. The criteria used to model wave energy device suitability in this assessment are listed in the table below.

Criteria	Units	Comments
Water depth (m)	Meters/fathoms	Depth between mean low tide and the seabed.
Distance from shore (nm) technical	Nautical miles	Straight-line distance from coast.
Seabed (type)	Description	Type of sediment on the surface of the seabed.
Sediment depth (m)	Meters	Depth of sediment overburden above bedrock.
Distance of deep-water port (nm)	Nautical miles	Navigable distance from a deep-water port.
Distance from service harbor (nm)	Nautical miles	Navigable distance from a shallow-water harbor.
Water currents (kts)	Knots	The velocity of water currents during mean spring conditions.
Tidal range (m)	Meters	The difference in height between mean low water springs and mean high water springs.
Seabed morphology	Description	Describes the shape of the seabed.
Distance to transmission lines (nm)	Nautical miles	The line-of-sight or Euclidean distance to the nearest transmission line.
Distance to substation (nm)	Nautical miles	The line-of-sight or Euclidean distance to the nearest substation.

An explanation of each of these criteria is provided in the following section.

Suitability Scores

For each of these criteria, a set of suitability scores was developed based on existing information on wave energy device types, interviews with inventor and developer representatives, and experiences from international development. Specifically, scoring reflects known specifications or requirements for anchoring and operating various wave energy devices. Preliminary scores were vetted with technology developers to validate assumptions, confirm existing technology drivers, develop common suitability scores among devices with technological similarities, and ensure that the relative suitability among wave energy devices was logical.

These scores range from zero to ten, with zero representing no potential for wave energy development and ten representing that the conditions observed are favorable for wave energy development in an economically-constrained environment. Ten intervening classifications are then determined in one-unit increments. Zero values are reserved for cases where the parameter overrides all other values, thus eliminating development potential.

It should be emphasized that while every effort has been taken to ensure that the scoring system is logical, credible, and reflective of reality, there may be specific issues associated with particular technologies that take that technology outside the notional class envelope. Given the early stage of technology development and the gradients that apply to most criteria, such deviations are not considered to be critical.

Explanation of Scoring

The following table describes factors used to score the suitability of particular wave energy devices and provides and explanation of the scoring methodology.

Water Depth

Technology	Scoring Explanation
Coastline converter	• The water depth at the coast is considered to be limited to less than 30 m. Therefore, no coastal device can have a water depth greater than 30 m. • Depths of 10 m to 30 m are considered ideal. • Depths of less than 10 m are considered to be less favorable.
Coastal surge	• Given the need for the wave to be creating surge type motion, the water depth range is limited to 10–20 m. • Waters shallower than 10 m will not yield enough exploitable energy. • Waters deeper than 20 m will not generate sufficient surge.
Offshore pressure	• This device works off a pressure differential between wave peaks and troughs; hence, the shallower the water the better. • An upper depth limit is considered to be 50 m. • There is a limit towards the shore in shallow water (less than 10 m) where conditions become less favorable due to sediment concerns.
Offshore point absorber	• The need for floating device clearance from the seabed leads to a minimum depth of approximately 30 m. • The reduction in wave energy due to bottom drag creates a threshold of approximately 50 m. • The cost of moorings makes an upper viability threshold of approximately 80 m. • The absolute limit on depth does not exist beyond cost. • All devices have similar requirements.
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance from Shoreline

Technology	Scoring Explanation
Coastline converter	• This technology is on the coast already.
Coastal surge	• All suitable water depths lie within 2 nm of the coastline. • The nearer the coastline, the better, due to the need to pump water ashore.
Offshore pressure differential	• Suitable depths lie between 1 nm and 5 nm from shore.
Offshore point absorber	• There are no suitable deployment areas within 1 nm, and reflected waves from any cliff-like coast could be a problem. • Between 1 and 4 nm from the shore is considered optimal. • At greater distances, cabling and service vessel costs will increasingly be a disadvantage. • These types of cost pressures are considered greater during pilot-scale testing.
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Seafloor Type

Technology	Scoring Explanation
Coastline converter	• Bedrock is considered to be the best foundation for such devices; increasingly fine sediments create increasing problems due to sediment dispersal in rough seas.
Coastal surge	• Bedrock is considered to be the best foundation for such devices; sand and gravel is a close second, while other materials are less favorable.
Offshore pressure	• Sedimentary seabed types are considered preferable to loose sediment types.
Offshore point absorber	• Sand and mud are considered to have the best anchor holding capacities for all of these technologies. Rock is less favorable but is possible to anchor to.
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Deep-Water Port

Technology	Scoring Explanation
Coastline converter	• Developments serviced from land rather than sea.
Coastal surge	• Within 20 nm, but not right on top of the harbor is best for all developments; early schemes will need to be closer to a home port (less than 50 nm) than will be the case for later larger schemes.
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance from Service Harbor

Technology	Scoring Explanation
Coastline converter	• Developments serviced from land rather than sea.
Coastal surge	• Similar to the need for deep-water ports above but without same need for clearance around harbors.
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Transmission Line

Technology	Scoring Explanation
Coastline converter	• The closer a wave energy device is to transmission line, the better. • In an economically-constrained environment, it is not feasible to site a wave energy device more than 6 nm from the nearest transmission line. • Distance to transmission is calculated as the line-of-sight or Euclidean distance to the nearest transmission line.
Coastal surge	
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Substation

Technology	Scoring Explanation
Coastline converter	• While connecting to a substation is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. • Thus, even in an economically-constrained environment, closer proximity to a substation is favorable. • The distance to a substation scoring is designed to reflect the less critical nature of the attribute.
Coastal surge	
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

APPENDIX F

Industry Outreach Tech Memo

TECHNICAL MEMORANDUM

Date:	January 11, 2012
To:	Jason Busch, Oregon Wave Energy Trust
From:	Ann Radil and Kevin Halsey, Parametrix
Subject:	Industry Outreach
Project Number:	283-6309-001 (01/02)
Project Name:	Cumulative Effects Phase II

INDUSTRY OUTREACH

Wave energy development companies and representatives that have actively participated in the development of the coastal, mid-depth, and offshore wave energy device suitability models used in the Oregon Wave Energy Trust's Cumulative Effects Framework include:

- Aquamarine, Donal MacNioclais
- Ocean Power Technologies, Robert Lurie and George Wolff
- Columbia Power Technologies, Reenst Lesemann
- Oregon Iron Works, David Gibson
- M3 technology, Mike Morrow
- Wello Direct Conversion, Represented by Gareth Davies of Aquatera
- Poseidon Floating Power and Science Applications International Corp, Rick Williams
- Pacific Energy Ventures, Justin Klure