# FY15 PROJECT PROPOSAL SUMMARY PAGE
## New Project

**Project Title:** Lingering Oil in Prince William Sound, Alaska:
1) Update of the Spatial Synthesis of Lingering Oil Distribution Modeling with 2013 Population Data for Sea Otters; and
2) Selection and Treatment Methods/Costs for Priority Lingering Oil Sites

**Project Period:** November 25, 2014 – September 30, 2015

**Primary Investigator(s):**
Jacqueline Michel, Ph.D., Research Planning, Inc., jmichel@researchplanning.com
Michel Boufadel, Ph.D., New Jersey Institute of Technology, boufadel@gmail
Zachary Nixon, Research Planning, Inc., znixon@researchplanning.com

**Abstract:**
The results of previous EVOS-funded work on modeling of the lingering subsurface oil in PWS on adjacent shorelines were correlated with reduced probability of suitable habitat use by sea otters in 1998 and 2008. This work will repeat the spatial modeling of the distribution of sea otters in 2013 to determine if this effect persists through 2013, the most recent year for which population data for sea otters in PWS are available. In addition, a desk-top exercise will be conducted to determine likely treatment methods and estimated costs for restoration of sites selected based on existing site field data, statistical modeling studies, and the field bioremediation study of four beaches. Modeling results for the locations of lingering subsurface oil will be used to produce a database of sites contaminated with moderate oil residue (MOR) and heavy oil residue (HOR). Sites with the same level of contamination will be added to the database. For each site in the database, the Principal Investigators will evaluate approaches for accelerating the removal of the lingering oil. The evaluation will include assessment of the technical (engineering) feasibility and cost. The appropriate approaches will be ranked and presented.

**Estimated Budget:**
**EVOSTC Funding Requested*** (*must include 9% GA)*:

| FY15 | FY16 | FY17 | FY18 | FY19 | TOTAL |
|---|---|---|---|---|---|
| **$114,570** | | | | | **$114,570** |

*(Funding requested must include 9% GA)*

**Non-EVOSTC Funds to be used:**

| FY15 | FY16 | FY17 | FY18 | FY19 | TOTAL |
|---|---|---|---|---|---|
| | | | | | **0** |

**If the amount requested here does not match the amount on the budget form, the request on the budget form will be considered to be correct.*

**Date: 2 September 2014**

## I. NEED FOR THE PROJECT
### A. Statement of Problem

The EVOS Trustee Council (EVOSTC) has funded several studies addressing the persistent, lingering subsurface oil from the 1989 *Exxon Valdez* oil spill. These studies have included: (1) locating the remaining lingering oil, using modeling and field sampling; (2) identifying the factors that have slowed natural removal of the oil; (3) identifying and evaluating candidate bioremediation technologies; (4) evaluating the potential for biodegradation of *Exxon Valdez* oil in laboratory columns (5) pilot testing of candidate bioremediation technologies; and (6) determining the linkage between lingering oil on the shoreline and habitat use by recovering species, namely sea otters and harlequin ducks.

As a result, Michel et al. (2010) developed a series of models to generate spatial data identifying the locations of various degrees of subsurface oil and potential sizes of the patches of the subsurface oil. Venosa et al. (2010) showed that that more than 80% of the total polycyclic aromatic hydrocarbons (tPAHs) biodegrade within six months when exposed to an environment rich with dissolved oxygen and nutrients. Results from the "Limiting Factors" project by Dr. Michel Boufadel revealed (Li and Boufadel, 2010; Boufadel et al., 2010) that the nutrient concentration was an order of magnitude lower than needed for maximum oil biodegradation. However, the major finding was that the dissolved oxygen concentration at oiled pits was the main limiting factor for biodegradation; in general, the concentration was less than 1.0 mg/L, and concentrations below 2.0 mg/L result in anoxic conditions where the biodegradation rate of oil is essentially zero.

Nixon et al. (in review) examined the relationships between the spatial distribution of the results from the revised subsurface shoreline oil probability models from the *Exxon Valdez* oil spill with the distribution of population, health, and oil exposure metrics of recovering species, as moderated by the presence of suitable nearshore habitat, in western Prince William Sound (PWS). The study results indicated that sea otters were underutilizing available habitat in PWS in the years investigated and that higher amounts of nearby intertidal subsurface oil correlated with where this underutilization was occurring both in 1998 and 2008. They found some evidence that harlequin ducks may have been underutilizing areas of suitable habitat with higher levels of nearby oiling in western PWS in 2000, but little evidence remained for the same correlation in 2008. To determine if sea otters continue to be underutilizing available habitat, this study will use the same methods to analyze the population data for sea otters in western PWS in 2013, the most recent date for which population data are available. This updated analysis is needed because recent population and pathology studies of sea otters in western PWS indicate that the population in this area has achieved the recovery objectives set by the EVOSTC for this species (Ballachey et al. 2014a, b; Bodkin et al. 2012).

Various studies funded by the EVOSTC have greatly advanced the understanding of the geomorphological and hydrological factors that have contributed to the persistence of subsurface oil from the *Exxon Valdez* oil spill (Hayes et al. 2010; Michel et al. 2010; Nixon et al. 2013; Nixon et al. in review; Li and Boufadel, 2010; Xia et al., 2011; Guo et al., 2011). The results of pilot studies at four sites by Boufadel have provided the basis for selecting sites where injection of nutrients and oxygen would be most effective. This new study will use the combined

knowledge from all previous work on PWS beaches to identify the best candidate sites and methods for restoration of the habitat where lingering oil is most likely to be found.

## II. PROJECT DESIGN

### A. Objectives

The objectives of the project are:

1. Determine if sea otter distributions in western PWS continue to show a correlation with the distribution of lingering subsurface oil; and

2. Identify the locations of heavier amounts of lingering subsurface oil, determine the optimal method for restoring these sites, and estimate the costs of the selected methods.

This work is important because of concerns that lingering oil continues to expose intertidal resources to EVO and is a factor in the recovery of injured resources. As long as the oil persists, particularly the subsurface oil that is slightly to moderately weathered and still bioavailable, there will be concerns about its effects. Also, users of intertidal resources, including subsistence users, will continue to be concerned about the safety of these resources.

### B. Procedural and Scientific Methods

The work will be conducted in the following tasks.

Task 1. Repeat the spatial modeling of the distribution of sea otters in 2013 to determine if an underutilization of oiled areas persists through 2013.

We will use existing indices of the relative amount of nearby shoreline oiling of three different types at three different spatial scales derived from previous machine-learning based modeling work (Nixon and Michel, in review). We will then construct a statistical habitat suitability/preference model for sea otters (*Enhydra lutris*) using survey data from 2013 and relevant environmental variables via the same maximum entropy (MaxEnt) presence-background modeling methods employed in earlier work for sea otters using survey data from 1998 and 2008. We will then statistically compare the performance of this model with and without inclusion of oiling index variables. Finally, we will test the values of oiling index variables at actual species occurrence locations of sea otters from 2013 versus random background locations across the survey footprint before and after accounting for habitat suitability/preference as predicted by the habitat preference models.

If habitat suitability/preference models are significantly improved after inclusion of oiling index variables and oiling index variables are significantly higher at background locations after accounting for habitat suitability, this may provide evidence that lingering oil is continuing to affect the distribution of sea otter population in the western PWS despite the fact that the total population has recovered to pre-spill levels. Conversely, lack of model improvement or higher index values at background locations will indicate that lingering oil presence is not a factor affecting the distribution of the sea otter population.

Task 2. Identify the most promising sites in PWS for restoration of the lingering oil.

We will use all available data to generate a list of the known and high-probability modeled sites of lingering subsurface oil, focusing on the sites with moderate oil residue (MOR) and heavy oil residue (HOR). We will develop a list of the key geomorphic and hydrologic factors that we will use to evaluate each site in terms of the likelihood of oil presence in treatable amounts. We will then review all of the available data for each site, including field data and ShoreZone imagery, to determine the likely presence or absence of subsurface oil. For the best candidate sites, we will then determine potential restoration areas. The result of this task will be a list of sites, their characteristics, a summary of what is known in terms of actual oil locations, oiling history, and other pertinent data.

Task 3. Determine restoration methods and costs for the priority sites.

The restoration methods for oiled shorelines will be evaluated by considering only the technical feasibility and predicted disruption of each method, the estimated cost, and the achievable endpoints (for example mass of oil per kilogram of sediments or concentration of polycyclic aromatic hydrocarbons, PAHs). Addressing the technical feasibility, the cost, and the endpoint of methods is a necessary step to identify potential candidate sites for restoration, but there are other factors that the EVOSTC would need to consider to reach its final decision on restoration. These factors include benefits to injured resources, public comments, and public health likely to be gained by restoration. The valuation of these factors is beyond the scope of this project.

In general, the sequence of restoration methods by increasing level of disturbance is as follows: Monitored Natural Attenuation (MNA), bioremediation, using manual labor to remove oil from the beaches using hand tools and collecting the oil using absorbing pads, hot water steaming, and site excavation. The cost of each method, however, does not associate with its degree of intrusiveness. MNA is the least intrusive and the least costly, but bioremediation, which ranks second in terms of lack of disturbance, could be costly. In all methods, one needs to consider the cost of waste transportation and disposal. In terms of endpoints, MNA and bioremediation do not reduce much of the mass of oil, rather its bioavailable fraction, such as the PAHs, which are the most toxic components of oil. Physical removal would remove total oil but requires dealing with the disposal of wastes.

We propose to create a matrix of methods based on the four categories proposed above, and to calculate the cost using engineering methods. Dr. Boufadel is a Professional Engineer and has considerable expertise working on the EVOS, and he will be collaborating closely with Dr. Michel who is a renowned oil expert with extensive expertise on the EVOS. Endpoints will be determined using best management practice (BMP) guidelines to ensure that the selected endpoint is achievable within the restoration method at a reasonable price.

Task 4. Prepare draft and final reports. Two separate reports will be submitted for review: 1) An update to the assessment of whether sea otters continue to underutilize areas of subsurface oil; and 2) An assessment of the priority sites, methods, and costs for restoration of lingering oil. We plan to publish the sea otter study in the peer-reviewed literature, as well.

**C. Data Analysis and Statistical Methods**
We will be working only with existing data and data compilations. We will be using the same statistical approaches as for our previous study "Spatial Evaluation of Effects of Persistent Subsurface Shoreline Oil from the *Exxon Valdez* Oil Spill on Recovering Species in Prince William Sound, AK," which is in review.

**D. Description of Study Area**
The project area will include those segments of shoreline in western PWS where lingering subsurface oil persists.

**E. Coordination and Collaboration**
This proposed study builds directly on our recently completed studies on the distribution of lingering oil, the limiting factors study, as well as studies by the Alaska Department of Fish & Game and the U.S. Geological Survey on the distribution of sea otters and harlequin ducks, among others.

**III. CV's/RESUMES (attached in Appendix A)**

**IV. SCHEDULE**
**A. Project Milestones**

| | |
|---|---|
| December 15, 2014 | Contract award |
| March 15, 2015 | Draft report on sea otter distributions |
| May 30, 2015 | Draft report on restoration sites and costs |
| 30 days after review | Final report |

**B. Measurable Project Tasks**

**FY 15, 1st quarter (December 15, 2014-December 31, 2014)**
Task 1. Conduct data compilation and analysis.

**FY 15, 2nd quarter (January 1, 2015-March 31, 2015)**
Task 1. Conduct all data compilation and analysis; submit draft sea otter modeling report
Task 2. Evaluate and select sites for restoration
Task 3. Determine restoration methods and costs; submit draft restoration sites and costs report

**FY 15, 3rd quarter (April 1, 2015-July 31, 2015)**
Task 3. Submit draft restoration sites and costs report
Task 4. Submit final reports

**V. BUDGET**
**A. Budget Spreadsheet (Attached)**
**B. Budget Justification**

**Personnel: amount requested FY15 - $ 99.1**
The personnel costs requested are for the hours estimated to complete the work.

**Travel: amount requested FY15– $ 0**
No travel is planned. All meetings will be held by conference calls and webinars.

**Contractual: amount requested FY15- $ 0**

**Commodities: amount requested FY15- $ 6k**

We have two papers on the supporting studies which are needed for this project that are in peer-review at leading journals. We have included the publication charges (estimated to be $5,000) for these two papers because our previous contract ended before the charges were incurred. We have also included $1,000 for phone, copies, and miscellaneous charges.

**Equipment: amount requested FY15- $0k**

## VI. REFERENCES CITED


Ballachey, B.E., D.H. Monson, G.G. Esslinger, K. Kloecker, J. Bodkin, L. Bowen, and A.K. Miles. 2014a. 2013 update on sea otter studies to assess recovery from the 1989 *Exxon Valdez* oil spill, Prince William Sound, Alaska: U.S. Geological Survey Open-File Report 2014-1030, 40 p.

Ballachey, B.E., D.H. Monson, K.A. Kloecker, G.G. Esslinger, F.C. Mohr, T.P. Lipscomb, M.J. Murray, and S. Howlin. 2014b. Synthesis of nearshore recovery following the 1989 *Exxon Valdez* oil spill: Sea otter liver pathology and survival in Western Prince William Sound, 2001 – 2008, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Projects 070808 and 070808A), U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska.

Bodkin, J.L., B.E. Ballachey, and G.G. Esslinger. 2012. Trends in sea otter population abundance in Western Prince William Sound: progress toward recovery following the 1989 *Exxon Valdez* oil spill, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 10100750-Amendment), U.S. Geological Survey, Alaska Science Center).

Boufadel, M. C., Y. Sharifi, B.VanAken, B. A. Wrenn, and K. Lee. 2010. Nutrient and oxygen concentrations within the sediments of an Alaskan beach polluted with the *Exxon Valdez* oil spill. Environmental Science and Technology 44(19):7418-7424.

Guo, Q., H. Li., M. C. Boufadel, and Y. Sharifi. 2010. Hydrodynamics in a gravel beach and its impact on the *Exxon Valdez* oil spill, Journal of Geophysical Research, Ocean 115:C12077.

Hayes, M.O., J. Michel, and D.V. Betenbaugh. 2010. The intermittently exposed, coarse-grained gravel beaches of Prince William Sound, Alaska: Comparison with open-ocean gravel beaches. J. Coastal Research 26(1):4-30.

Michel, J., Nixon, Z., Hayes, M. Short, J., Irvine, G., Betenbaugh, D., and C. Boring. 2009. Modeling the Distribution of Lingering Subsurface Oil from the *Exxon Valdez* Oil Spill. Final Report, EVOS Restoration Project 070801.

Li, H., M. C. Boufadel. 2010. Long-term persistence of oil from the *Exxon Valdez* spill in two-layer beaches, NATURE geosciences 3:96-99.

Nixon, Z., J. Michel, M.O. Hayes, G. Irvine, and J. Short. 2013. Geomorphic factors controlling the persistence of subsurface oil from the *Exxon Valdez* Oil Spill. Journal of Coastal Research 69:115-127.

Nixon, Z. and J. Michel. In review. Predictive modeling of lingering subsurface shoreline oil encounter probability from the *Exxon Valdez* oil spill in Prince William Sound, AK. Submitted to Environmental Science & Technology.

Nixon, Z., J. Weaver, and J. Michel. In review. Spatial evaluation of effects of persistent subsurface shoreline oil from the *Exxon Valdez* oil spill on recovering species in Prince William Sound, AK. Submitted to Ecological Modeling.

Short, J.W., M.R. Lindeberg, P.M. Harris, J.M. Maselko, J.J. Pella, and S.D. Rice. 2004. Estimate of oil persisting on the beaches of Prince William Sound 12 years after the *Exxon Valdez* oil spill. Environmental Science & Technology 38(1):19-25.

Short, J.W., J.M. Maselko, M.R. Lindeberg, P.M. Harris, and S.D. Rice. 2006. Vertical distribution and probability of encountering intertidal *Exxon Valdez* oil on shorelines of three embayments within Prince William Sound, Alaska. Environmental Science & Technology 40:3723-3729.

Venosa, A.D., P. Campo, and M.T. Suidan. 2010. Biodegradability of lingering crude oil 19 years after the *Exxon Valdez* oil spill. Environ. Sci. Technol. 44:7613-7621.

Xia, Y., H. Li., and M. C. Boufadel. 2010. Factors affecting the persistence of the *Exxon Valdez* oil on a shallow bedrock beach, Water Resources Research 46, W10528, 17 p.

**APPENDIX A**

2-page resumes for:

Jacqueline Michel
Zach Nixon
Michel Boufadel

**JACQUELINE MICHEL, Ph.D.** **Research Planning, Inc.**
Geochemist, President since 2000, Founder in 1977
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## Education

Ph.D., Department of Geology, University of South Carolina (USC), Columbia (1980).
M.S., Department of Geology, USC, Columbia (1976).
B.S., Department of Geology, USC, Columbia (1974)

**Five most recent publications most closely related to the proposed project**

Nixon, Z. and J. Michel. In review. Predictive modeling of lingering subsurface shoreline oil encounter probability from the *Exxon Valdez* oil spill in Prince William Sound, AK. Submitted to Environmental Science & Technology.

Minter, T.G., J.A, Hale, C.D. Cormack, L. Cotsapas, and J. Michel. 2014. Tidal flat and sand beach remediation: Choosing remediation techniques to speed ecological recovery of habitats still impacted 20 years after the Gulf War oil spill. Proc. 2014 International Oil Spill Conference, American Petroleum Institute, Washington, D.C. pp. 1719-1733.

Nixon, Z., J. Michel, M.O. Hayes, G.V. Irvine, and J. Short. 2013. Geomorphic factors related to the persistence of subsurface oil from the *Exxon Valdez* oil spill. Journal of Coastal Research, Special Issue No. 69:115-127.

Boufadel, M.C., B.A. Wrenn, B.E. Moore, K.J. Boda, and J. Michel. 2011. A biodegradation assessment tool for decision on beach response. Proc. 2011 International Oil Spill Conference, American Petroleum Institute, Washington, D.C., 19 pp.

Michel, J., Z. Nixon, M.O. Hayes, J. Short, G. Irvine, D. Betenbaugh, C. Boring, and D. Mann. 2010. Distribution of subsurface oil from the *Exxon Valdez* oil spill. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 070801), National Oceanic and Atmospheric Administration, Juneau, AK. 121 pp. + app.

**Five other significant publications**

Michel, J. and N. Rutherford. 2014. Impacts, recovery rates, and treatment options for spilled oil in marshes. Marine Pollution Bull. 82(1-2):19-25.

Michel, J., E.H. Owens, S. Zengel, A. Graham, Z. Nixon, T. Allard, W. Holton, P.D. Reimer, A. Lamarche, M. White, N. Rutherford, C. Childs, G. Mauseth, G. Challenger and E. Taylor. 2013. Extent and degree of shoreline oiling: *Deepwater Horizon* oil spill, Gulf of Mexico, USA. PLoS ONE 8(6):e65087.

Zengel, S. and J. Michel. 2013. *Deepwater Horizon* Oil Spill: Salt Marsh Oiling Conditions, Treatment Testing, and Treatment History in Northern Barataria Bay, Louisiana (Interim Report October 2011). U.S. Dept. of Commerce, NOAA Technical Memorandum NOS OR&R 42. Seattle, WA: Emergency Response Division, NOAA. 74 pp.

Michel, J. and M.O, Hayes. 1999. Weathering patterns of oil residues eight years after the *Exxon Valdez* oil spill. Marine Pollution Bull. 38:855-863.

Hayes, M.O. and J. Michel. 1999. Factors determining the long-term persistence of *Exxon Valdez* oil in gravel beaches. Marine Pollution Bull. 38:92-101.

**Collaborators on a project or publication within the last four years**

Sarah Allen, Office of Response and Restoration, NOAA
David Anderson, National Park Service
Gary Andrews, U.S. Environmental Protection Agency
Mary Baker, Office of Response and Restoration, NOAA
Adriana Bejarano, Research Planning, Inc.
Brad Benggio, Office of Response and Restoration, NOAA
Michel Boufadel, New Jersey Institute of Technology
Greg Challenger, Polaris Applied Sciences, Inc.
Carl Childs, Office of Response and Restoration, NOAA
Josie Clark, U.S. Environmental Protection Agency
Mary Cocklan-Vendl, BP
Frank Csulak, Office of Response and Restoration, NOAA
Gregg Douglas, Newfields
Ralph Dollhopf, U.S. Environmental Protection Agency
Michael Donlan, Industrial Economics, Inc.
Jim Elliott, T&T Marine
Dagmar Etkin, ERC
Leslie Genova, Industrial Economics, Inc.
James Gibeaut, Texas A&M University
Andy Graham, Polaris Applied Sciences, Inc.
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## EDUCATION

Duke University, Durham North Carolina - Master of Environmental Management, 2006
University of South Carolina, Columbia, S.C - B.S., Marine Science, 1997

**Five most recent publications most closely related to the proposed project**

Nixon, Z. and J. Michel. In review. Predictive modeling of lingering subsurface shoreline oil encounter probability from the *Exxon Valdez* oil spill in Prince William Sound, AK. Submitted to Environmental Science & Technology.

Nixon, Z., J. Weaver, and J. Michel. In review. Spatial evaluation of effects of persistent subsurface shoreline oil from the *Exxon Valdez* oil spill on recovering species in Prince William Sound, AK. Submitted to Ecological Modeling.

Nixon, Z. Michel, J., Hayes, M.O., Irvine, G. and Short, J. 2013. Geomorphic factors controlling the persistence of subsurface oil from the Exxon Valdez Oil Spill. Journal of Coastal Research, 69:115-127.

Michel, J., Nixon, Z., Hayes, M., Irvine, G. and S. Short. 2011. The distribution of lingering subsurface oil from the *Exxon Valdez* oil spill. Proc. In: 2011 International Oil Spill Conference, American Petroleum Institute.

Michel, J., Nixon, Z., and L. Cotsapas. 2005. Evaluation of oil remediation technologies for lingering oil from the Exxon Valdez Oil Spill in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Report #050778.

**Five other significant publications**

Zengel, S., Bernik, B., Rutherford, N., Nixon, Z., Michel J., and Csulak, F. 2014. Salt marsh remediation and the *Deepwater Horizon* oil spill, the role of planting in ecological recovery. Conference Abstract. Gulf of Mexico Oil Spill & Ecosystem Science Conference.

Zengel, S., Rutherford, N., Nixon, Z., Bernik, B., and Michel, J. 2013. Cleanup of heavilly oiled salt marsh during the *DWH* oil spill: II. Comparisons of ecological effects and initial recovery. Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA.

Michel, J., Owens, E.H., Zengel, S., Graham, A., Nixon, Z., Allard, T., Holton, W., Reimer, P.D., and Lamarche, A. 2013. Extent and degree of shoreline oiling: *Deepwater Horizon* oil Spill, Gulf of Mexico, USA. PLoS ONE 8(6): e65087.

Zengel, S., Rutherford, N., Bernik, B., Nixon, Z., and Michel, J. 2014. Salt marsh remediation and the *Deepwater Horizon o*il spill, the role of planting in vegetation and macroinvertebrate recovery. Conference Abstract. 2014 International Oil Spill Conference.

Michel, J., Nixon, Z., Dahlin, J., Betenbaugh, D., White, M., Burton, D., and S. Turley. 2009. Recovery of interior brackish marshes seven years after the Chalk Point oil spill. Marine Pollution Bull. 58:995-1006.

**Collaborators on a project or publication within the last four years**

Theresa Allard, Polaris Applied Sciences
Mary Baker, NOAA
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Miles O. Hayes, Research Planning, Inc.
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William Holton, Research Planning, Inc.
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Nicolle Rutherford, NOAA
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Marla Steinhoff, NOAA
Doug Reimer, Environmental Mapping Ltd
Jonathon Willis, University of Louisiana
Scott Zengel, Research Planning, Inc.

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| | | |
|---|---|---|
| Ph.D. | Environmental Engineering, University of Cincinnati, Cincinnati, Ohio. | 1998 |
| M.S. | Environmental Engineering, University of Cincinnati, Cincinnati, Ohio. | 1992 |
| B.S. | Civil Engineering, *Hydraulics Option*, Jesuit University at Beirut, Lebanon. | 1988 |

**EXPERIENCE**

| | |
|---|---|
| July 2012-present | Director, Center for Natural Resources Development and Protection, New Jersey Institute of Technology |
| July 2012- present | Professor, Department of Civil and Environmental Engineering New Jersey Institute of Technology. |
| Sept. 2009-June 2012 | Director, Center for Natural Resources Development and Protection, Temple University. |
| June 2006-June 2011 | Chair, Department of Civil and Environmental Engineering Temple University. |
| January 2010- 06/2012 | Professor, Courtesy Appointment in the Department of Earth and Environmental Science, Temple University. |
| July 2008- June 2012 | Professor, Department of Civil and Environmental Engineering Temple University. |
| July 2005-June 2008 | Associate Professor, Department of Civil and Environmental Engineering, Temple University. |
| Sept. 1999-June 2005 | Assistant Professor, Department of Civil and Environmental Engineering, Temple University. |

**RESEARCH EXPERTISE**

1) Coastal hydrology and hydraulics. 2) Oil biodegradation. 3) Transport of chemicals and sediments in estuaries, and 4) Environmental assessment of large-scale systems.

**Five most recent publications most closely related to the proposed project**

Bobo, A. (Graduate Student), H. Li, and M. C. Boufadel, Groundwater flow in a tidally influenced gravel beach in Prince William Sound, Alaska, Journal of Hydrologic Engineering, ASCE, 17(4), 478-494, 2012.

Abdollahi-Nasab (Graduate Student), A., M. C. Boufadel, Li, H., and J. W. Weaver, Saltwater flushing by freshwater in a laboratory beach, Journal of Hydrology, 386,1-12, 2010.

Li, H.(Postdoctoral fellow), M. C. Boufadel, and J. W. Weaver, Tide-induced seawater-groundwater circulation in shallow beach aquifers, J. of Hydrology, 211-224, 2008.

Boufadel, M.C., H. Li, H., M.T. Suidan, and A.D. Venosa. Tracer studies in a laboratory beach subjected to waves. J. Environmental Engineering, ASCE, 133 (7), 722-732, 2007.

Boufadel, M.C., M.T. Suidan, and A.D. Venosa. Tracer studies in a laboratory beach simulating tidal influences. J. Environmental Engineering, ASCE, 132(6):616-623, 2006.

**Five other significant publications**

Boufadel, M. C., Y. Xia, and H. Li, Modeling solute transport and transient seepage in a laboratory beach under tidal influence, Environmental Modeling Software,26 (7), p.899, 2011.

Li, H. (Postdoctoral Fellow), M. C. Boufadel, Long-term persistence of oil from the Exxon Valdez spill in two-layer beaches, NATURE geosciences, 3, 96-99, 2010.

Boufadel, M. C., Y. Sharifi, B.Van Aken, B. A. Wrenn, and K. Lee, Nutrient and oxygen concentrations within the sediments of an Alaskan beach polluted with the *Exxon Valdez* oil spill, Environmental Science and Technology, 44 (19), p 7418–7424, 2010.

Xia, Y (Graduate Student), H. Li, M. C. Boufadel, Q. Guo, and G. Li, Tidal wave propagation in a coastal aquifer: effects of leakages through its submarine outlet capping and offshore roof, J. of Hydrology, doi:10.1016/j, 2007.

Boufadel, M. C., M. T. Suidan, A. D. Venosa, and M. T. Bowers. Steady seepage in trenches and dams: Effect of capillary flow, J. of Hydraulic Engineering, ASCE, Vol. 125, p 286-294, 1999.

**Collaborators on a project or publication within the last four years**

Atkins, D., Environmental Research
Beegle-Kraus, C.J., SINTEF
French-Mackay, D., RPS ASA
Lee, K., COOGER
Li, Z., RPS ASA
Michel, J., Research Planning, Inc.
Short, J., Private Consultant
Suidan, M., University of Cincinnati
Venosa, A., U.S. Environmental Protection Agency
Weaver, J., US EPA
Wrenn, B., Private Consultant
Adams, E., MIT
Socolofsky, S., Texas A&M
Suri, R., Temple University
Van Aken, B., Temple University

**OTHER:** Professional Engineer in New Jersey and Pennsylvania. Professional Hydrologist as accredited by the American Institute of Hydrology.

**Research Planning, Inc.**

| Sea Otter Model | | Option Year 2 Hours | NOAA Rates | Total |
|---|---|---|---|---|
| J Michel | PI | 8 | 210.30 | 1,682.40 |
| Zach Nixon | GIS Specialist | 80 | 105.29 | 8,423.20 |
| J Weaver | Bio2 | 72 | 69.64 | 5,014.08 |
| Total Salaries | | 160 | | 15,119.68 |

| Site Restoration Analysis | | Option Year 2 Hours | NOAA Rates | Total |
|---|---|---|---|---|
| J Michel | PI | 136 | 210.30 | 28,600.80 |
| Z Nixon | GIS Specialist | 88 | 105.29 | 9,265.52 |
| M Boufadel | Co-PI | 152 | 210.30 | 31,965.60 |
| F Saleh | Engineer | 176 | 75.00 | 13,200.00 |
| W Early | Editor | 16 | 59.88 | 958.08 |
| Total Salaries | | 568 | | 83,990.00 |

| Other Direct Cost | |
|---|---|
| Publication charges for the 2 papers in review | 5,000.00 |
| Phone/Mail/Misc. | 1,000.00 |
| Total Other Direct Cost | 6,000.00 |
| Total | 105,109.68 |
| G&A (9%) | 9,459.87 |
| Grand Total | 114,569.55 |