The Watersheds Project: Community-based Modeling to Support Watershed Quality

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Abstract

The Web browser has brought a new interactive, high-resolution graphical interface to the citizens of the world. Given the requisite visual literacy to help citizens cognate on geospatial presentations that technically could not have been presented in an online format a decade ago, communities can become smarter and wiser about conservation of water and water-related assets within their local watersheds. By integrating social-media to layer-based data visualization, software components can provide watershed councils and waterkeeper alliances tools with which to reach their local citizens and coordinate beneficial actions for watershed health.

In support of the above paragraph, this paper presents results from the Phase I work of the Watersheds Project and the motivation and agenda for Phase II as it is slated to unfold in the upcoming years 2012-15. We describe the Phase II system support architecture as currently envisioned by multiple partners interested in improving community participation in watershed quality discussions and actions – support for watershed councils and waterkeeper alliances in particular.

CR Categories: H.1.2 [Information Systems]: Visualization, Visual Literacy, Social Media Integration.

Keywords: watershed quality management, personal action, simulation, modeling, display mapping.

1 Introduction

On January 1, 2011, the Watersheds Project (WsP) began pursuing an organizational strategy as one of 43 fiscal-sponsored projects of The Ocean Foundation (TOF). Having spent years 2009 and 2010 as a sub-project of one of TOF's largest projects, The Ocean Project (TOP), the WsP has helped a global network of over 400 zoos, aquariums, and museums (ZAMs) consider educating their millions of visitors about how they can help protect and conserve our watersheds through awareness and personal action [1]. Another 1250 conservation and education organizations consider themselves partners of TOP, many of which already participate in watershed quality activities.

Both TOP and WsP make an impact that is significantly enhanced by electronic mediated communications – coordinated through websites located on the Web at theoceanproject.org and watershedsproject.org. In October 2008, the precursor to the WsP was introducing its objectives through the title of Watersheds-to-Ocean Initiative (WOI). The WOI team was invited to present at the International Aquarium Congress in Shanghai, China and presented a paper entitled *Personal Connection to the Ocean Via On-line Interactive Experiences* [2]. The paper outlined work being done that we now consider Phase I of the WsP. We continue to document Phase I work on the Web at metothesea.org, including demonstrations of the interactive path to the sea virtual globe developed with Phase I funding.

The WsP organizational spin-off from TOP allows the WsP to focus on developing services for watershed councils and waterkeeper alliances without any perceived dilution of TOP's world-class service to zoos, aquariums, and museums. The WsP continues to pursue interest from those constituents but believes the best goal-aligned service can be provided to those watershed councils and waterkeeper alliances that are already gaining respect and focus as stewards of watershed health in their communities. We continue to expect zoos, aquariums and museums to work with regional watershed councils to promote each other's missions and improve watershed quality in visitor's watersheds – the watershed from which exhibit visitors get drinking water, the watersheds in which those visitors fish and recreate, and the watersheds that receive the outfall of those visitors' sewage and other waste products.

The opportunity to increase watershed awareness and action through Internet-based applications expands through the continually emerging capabilities of standard Web browsers – browsers that are rapidly evolving to present multimedia content, video content, and interactive applications thanks to JavaScript libraries and the emerging HTML 5 standard. Three-dimensional virtual Earth systems and Geographic Information Systems (GIS) are also integrated into browsers. Watershed councils often provide informational sites online but have yet to take advantage of available social media and integrated display mapping to coordinate watershed health.

The Web browser brings a new interactive, high-resolution graphical interface to the citizens of the world and offers the potential for world citizens to get to know the watershed councils of the world while contemplating the plight of their local watersheds. As competent browsing skills grow to include requisite a sophisticated level of visual literacy to help citizens cognate on geospatial presentations that technically could not have been presented in an online format a decade ago, the WsP believes communities can become smarter and wiser about conservation of water and water-related assets within their local watersheds. By integrating social-media to layer-based data visualization, Phase II of WsP software contribution can provide watershed councils and waterkeeper alliances tools with which to reach their local citizens and coordinate beneficial actions for watershed health.

Local natural visualization layers have yet to be coordinated satisfactorily from the ecological address perspective promoted by the WsP, TOP, and various environmental educators [3]. Phase II continues to aim to change public perception by generating and promoting a well-documented process for building visualization layers for the planet on a watershed-by-watershed basis – with the addition of incorporating those layers into a watershed modeling tool for watershed council promotion and use. Modeling layers are the same layers our partners can use to educate their communities about personal actions they can take on the behalf of watershed health. Phase I focused on providing social media for discussing visual layers of watershed data for community use. Phase II focuses on using those layers in an interactive watershed modeling process for better watershed natural cycle understanding and consideration among citizens. Without understanding those cycles, climate change becomes a more difficult concept for communities to prepare for and consider. Funding choices for specific watershed health activities often lack consensus.

2 Phase I Work

As presented in Shanghai four years ago, the WsP's first order of business as an entity was to improve the public's appreciation of the word *watershed* – a word that scientific and political organizations use to describe their local rain catchments when studying and acting to improve local community health. In 2008, the word watershed was not resonating well with the general public and resonance is a major component of awareness and motivation. When we performed a search on the word watershed on www.google.com on July 1, 2008, we found we had access to about 1.2 million results in our browser. The same search on July 1, 2012 provided about 9.4 million results (an almost eight times increase). For better or worse, the word watershed does not seem to be disappearing in document use online.

Phase I work included development of an application that visualizes the local watershed in which any location on Earth is contained. By clicking on a NASA-developed virtual globe, a Web visitor could see the path of drainage of that location to the sea. Figure 1 shows a screenshot of the *Me To The Sea* visualization for a location within the Moshassuck Watershed in northern Rhode Island. In Figure 3, the watershed boundary is yellow and path to the sea is blue.

Phase I work included the implementation of iterative process improvement activities into software development. The process of accessing, managing, editing, and processing important data layers within a watershed visualization system is more complicated than the process of creating and editing community Web encyclopedia pages, such as the process developed by Wikipedia. Although WsP long-term goals include building intuitive tools and tutorials, we need to develop legions of experienced people (or at least one very motivated individual in each watershed) who can perform the necessary data management tasks and teach others to do so as well.

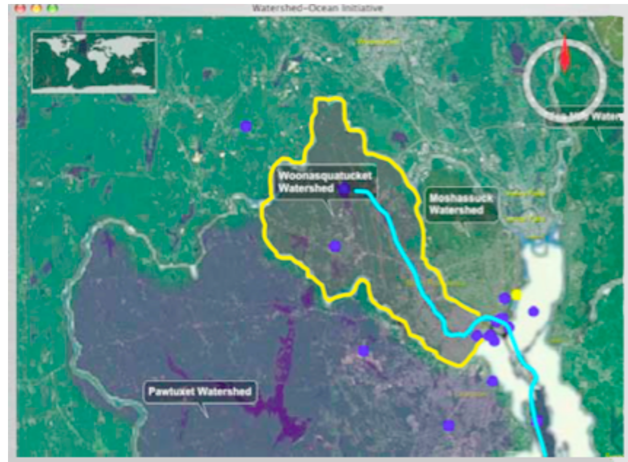

Figure 1: Watershed boundary and drainage path to the sea on top of NASA World Wind globe satellite image layer.

For the benefit of building better watershed quality tools, we evolve recommended data-processing processes and demonstrate them as a member of a watershed quality community – listening to our partners, their constituents, and volunteers who attempt to contribute through guided collaboration and provide feedback as to quality and reproducibility. In this capacity, the WsP takes on the role of a mediator to help promote successful data layers and successful social mediation across watershed communities.

Successful data capture, data processing, and data visualization techniques are promoted from within WsP managed software tools, but also via explanatory and promotion pages shared with partners. By behaving as a central moderator who coordinates the set of tools, we expect to be as successful in empowering communities to improve their watershed quality as Linus Torbalds has been in empowering system administrators to build useful software [5], Wikipedia management has been in empowering world citizens to support open information processes [6], or Tim Bernards-Lee has been in empowering people to connect and communicate effectively on the World Wide Web [7].

We count upon having at least two advantages many other information processing coordinators have not had: first, our information is geospatially tagged and thus naturally easy to organize with presentation upon a globe and, second, public opinion studies have shown that most world citizens already have a very strong emotional connection with the ocean [8], upon which we can build an awareness that watershed quality effects ocean quality.

Besides coordinating a focus on the data layers to be made available in our tools, we see the need to coordinate:

- **roles and expectations** for community-building specialists,
- **visualization approaches** to presenting data,
- **interaction techniques** for supporting an

investigatory train of thought while using tools,
- **hierarchical organization** of sub-watersheds to aggregate up to a smooth global presentation, and
- **programming interfaces** for connecting subsystems to coordinating systems software.

Instead of just developing these tools in a vacuum for watershed council use, we see a future where our tools can provide useful experience for people as part of on-line classes on topics such as communication, geographical display mapping, and electronic-mediated workflow. These skills are critical to continuous improvement of each activity we perform on behalf of servicing watershed quality organizations.

Phase I partners who helped promote the Phase I application shown in Figure 1 (and provided feedback to help us improve our process for working with partners) included Save The Bay in Providence, RI and SoundCitizen in Seattle, WA. Save The Bay hosted a series of Web pages that integrated watershed boundaries and drainage paths into Narragansett Bay interactive visualization. The pages helped disseminate Save the Bay's educational objectives – including interactive result exploration from a bay health analysis that focused on dissolved oxygen by location in the bay.

SoundCitizen hosted a series of Web pages that integrated watershed boundaries and drainage paths into Puget Sound interactive visualization. The pages helped provide context to the citizen water quality project SoundCitizen made available through free water testing kits that were distributed to the general public. Location of citizen water samples along with results of PH levels and other health indicators were shown among watershed boundaries – facilitating watershed quality analysis consideration by Web visitors.

After piloting Phase I software through two wide area partners, we integrated applications into a social media platform and pilot tested a Drupal-based content management community tool for support of two watershed councils in northern Rhode Island: The Woonasquatucket River Watershed Council (WRWC) and Friends of the Moshassuck (FOTM, the Moshassuck watershed council).

Rhode Island is an ideal state for testing watershed council support tools, as the councils are coordinated well via a respected coordinating organization: the Rhode Island Rivers Council [4]. Rhode Island is also small enough that each watershed council has an awareness of all other councils and clearly acknowledges responsibility and accountability through watershed council board of directors. If any community could be served by socially-mediated communication tools, it seemed those within the watersheds that drained to Narragansett Bay would be most likely to thrive by such service.

3 Phase II Work

As WsP personnel became active members of both the WRWC and FOTM organizations, the opportunity for doing meaningful Phase II work became highly apparent. Phase II funding discussions began with acquiring technology partners in well-funded university research departments at the University of Washington and Brown University, both in which whom WsP personnel had known research staff before beginning Phase I work. Although 2012 appears to be in the midst of a non-profit research funding down cycle, Phase II work is beginning humbly towards the goals outlined below.

The WRWC and FOTM have been working to improve watershed quality through physical projects such as dam removal for fish habitat improvement and reforestation for invasive species control. Each such physical activity includes a component of uncertainty as to effectiveness of the physical act. Will the removal of dams on the Woonasquatucket River bring back herring runs without adversely affecting other biota? Will the forestation of the Collyer Field along the Moshassuck effectively block sunlight to aggressive Japanese Knotweed in the area without adversely affecting water quality? These questions are deemed critical to investigate to gauge success of the work that has been done.

In the case of both of these example projects, the watershed councils have received great praise in the community – officially from politicians who send letters and attend public acknowledgement presentations; and less officially from citizens who attend tours and celebrations of the affected watershed project locations. The praise and sense of accomplishment have resonated to empower organizational members to think about new activities to pursue to continue the momentum of their contributions. What possible projects are best to pursue? What is the best use of limited funding? Who in the community can be counted on to support future activities, and what activities are citizens willing to support with their checkbooks? These questions are deemed critical to investigate to gauge the possibilities of performing future actions.

As WsP personnel have watched both the WRWC and FOTM watershed council proceedings closely, we have realized the need for a comprehensive tool to help assess possible activities for contribution to overall watershed quality. Council activities are affecting the watershed physically, which suggests the need for a good physical model that can be used to consider watershed quality holistically. Software models have been quite effective in helping scientists consider watershed processes as a basis for considering man-made changes. As a result, the WsP is working to prototype the injection of hydrology modeling into Phase I technology support.

Researchers at The University of Washington in Seattle are leaders in maintaining and implementing software models for atmosphere, hydrology, and ocean circulation simulation of physical extents. Models have been implemented locally in the Puget Sound region but also for foreign locations around the world. As a result, the WsP is partnering with researchers to adapt hydrology-modeling tools for community use at the watershed scale of both the WRWC and FOTM – scales that seem to be at an optimal size for community consideration (extents that are not too large and not to small). The WsP will open up the process to participation by a wide variety of roles in the community with the intent of hoping their awareness and personal action will grow with a sense of co-ownership of the watershed quality improvement process.

WsP personnel have had the opportunity to discuss watershed health with people in many different societal roles in our society. Phase I work involved working side-by-side with those people and relying on the expertise gained from performing those roles. Some of the roles where people express empowered involvement with watershed health in their role include those roles represented in Figure 2. Consider the roles in Figure 2 in a clockwise manner from the upper-left.

We have experienced that the scientist wants to contribute their skill at analysis and hypothesis testing, the hiker wants to contribute their in-the-field awareness skills, the volunteer wants to contribute their time and resources, the artist wants to contribute their aesthetic skills, the informal learner wants to contribute their enthusiasm, the teacher wants to contribute their communication to young people skills, and the fisherman wants to contribute their in-the-water awareness skills.

Figure 2: Community roles with watershed quality interests.

Each of these roles provides a perspective the watershed council can consider when choosing activities to physically improve watershed quality. There are at least seven steps in watershed modeling in which those roles can participate:

- Watershed model data acquisition
- Watershed data ground-truthing
- Interactive model data inputs sharing
- Interactive model outputs sharing
- Web content generation
- Visual products dissemination
- Social-media support of the community effort

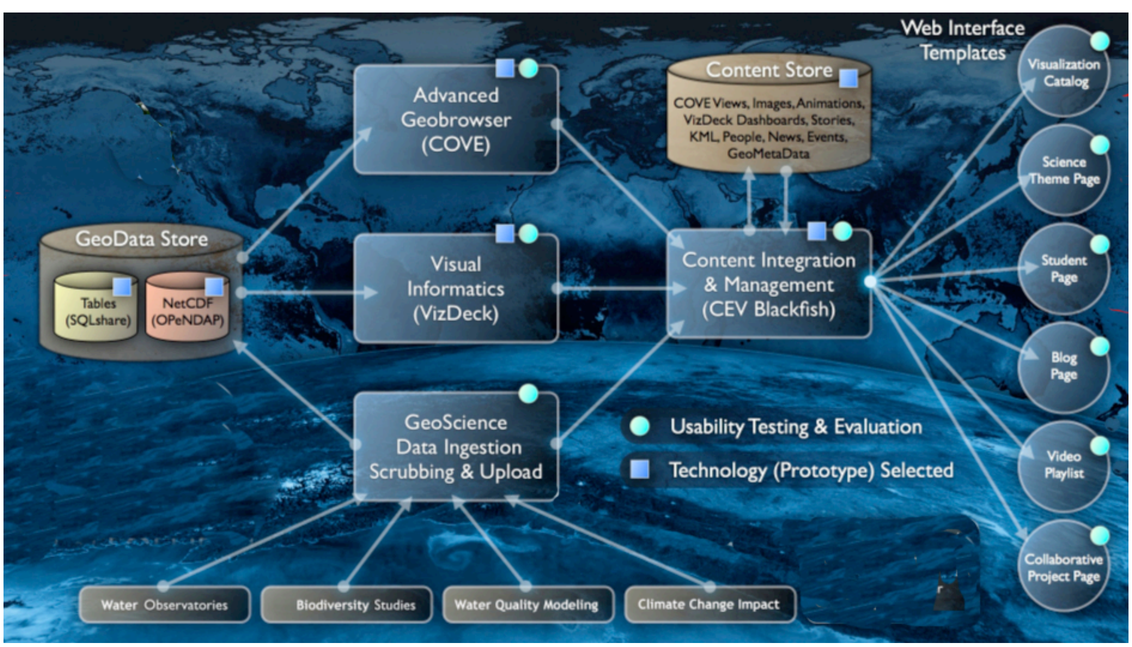

Figure 3 – The watershed quality content management pipeline

4 Community-based Modeling Integration

The watershed modeling process depends on the availability and correctness of geographic data in order to produce meaningful results. Interested members in the community can participate with their watershed council leadership to review the correctness of modeling input data and help acquire data points for data that is not available but necessary for any modeling process.

Figure 3 shows a process flow from left to right whereby the GeoData Store on the left is the starting point for producing useful watershed quality content for community use. Both relational and NetCDF data storage mechanisms are widespread in use when storing data associated with the natural world. Watershed councils and interested participants can be trained to use interfaces that allow review and edit of data stored in the store.

Scientists are key participants when they bring their evolved expertise to help the community become better data stewards. They are also invaluable when building software agents that can perform key data tasks. The GeoScience Data Ingestion Scrubbing & Upload process in Figure 3 is one of those software agents that can help keep data correct and appropriate for modeling tasks. As data is ingested, scrubbed, and uploaded back to the GeoData Store, it provides an opportunity for the community to participate in understanding the significance of each action taken by software. As data has been through the review by software agents and used by Water Observatories, Biodiversity Studies, Water Quality Modeling, and Climate Change Impact services (seen at the bottom of Figure 3), the results of those services are also made available for community review and consideration and maintained in the store.

As the store contains correct and complete data, visualization services provided by the WsP and its partners can be used to start the visualization pipeline that ends with Web-appropriate content as shown in the far right of Figure 3. The benefit of partnering with the University of Washington is the WsP does not need to reinvent geobrowser, informatics, and content integration processes that the UW has developed over many years. The COVE, VizDeck, and CEV Blackfish services are available for watershed councils uses through assistance by WsP activities on their behalf.

4.1 COVE Advanced GeoBrowser

As watershed quality monitoring outputs are produced to describe the state of the watershed in future time periods, the COVE advanced geobrowser affords visualization of data layers on a virtual landscape. By mixing and matching layers of interest to a geospatial extent, and then investigating change of those layers over time, watershed councils can internalize the suggested predictive state of the watershed given the input assumptions used in the modeling process. The presentation of each layer is under the control of the user.

As the COVE developers state:

> The Collaborative Ocean Visualization Environment (COVE) is a visualization system designed with oceanographers to combine the ease of use of applications like Google Earth with the needs of the scientific community. As well as being able to change scale and perspective at the science site, it also supports high-resolution bathymetry, color gradients to highlight the bathymetry, 3D visualization of datasets, and tracking and planning tools for working with oceanographic assets such as Autonomous Underwater Vehicles (AUVs).

The visualization system is equally useful for visualizing the state of the watersheds that provide freshwater to the ocean over time. For example, Figure 4 shows an example of soil depth of a watershed for consideration of sediment transport. Layers of water table, precipitation, soil moisture, and vegetation cover can be added to investigate sediment transport more fully. COVE provides watershed council investigation of modeling inputs and outputs benefit equally from visual techniques available.

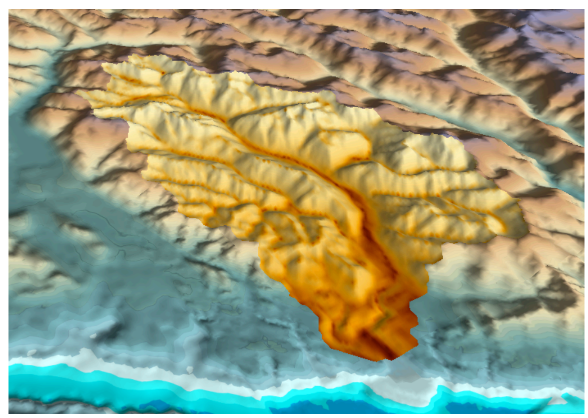

Figure 4 – Visualization of watershed soil depth using COVE

4.2 Visual Informatics (VizDeck)

As watershed councils gain access to key environmental data that describe the physical world in which they work in detail, visual analytical tools can help with the process of decision-making based on that data. Control panel dashboards build visual familiarity to widgets that communicate change over days, seasons, years, and decades – changes that effect the decision-making process by suggesting priority shifts to personal actions. The VisDeck visual informatics software suite allows watershed data to be displayed in common widgets that become familiar for watershed council review over time.

As the VizDeck developers state:

> VizDeck is a web-based visualization client for presenting relational data that uses a card game metaphor to assist users in creating interactive

visualization-based dashboard application in seconds with zero programming. VizDeck automatically generates a "hand" of ranked visualizations and user interaction widgets, and the user plays these "cards" into a dashboard template. By manipulating the hand dealt—playing good cards, sorting one's hand, and discarding unwanted cards—the system learns statistically which visualizations are appropriate for a given dataset, improving the quality of the hand dealt for future users.

Figure 5 shows an example of widget presentations for investigating monitored key environmental variables for a watershed. Familiarity of widget presentation helps a community discuss variable changes over time.

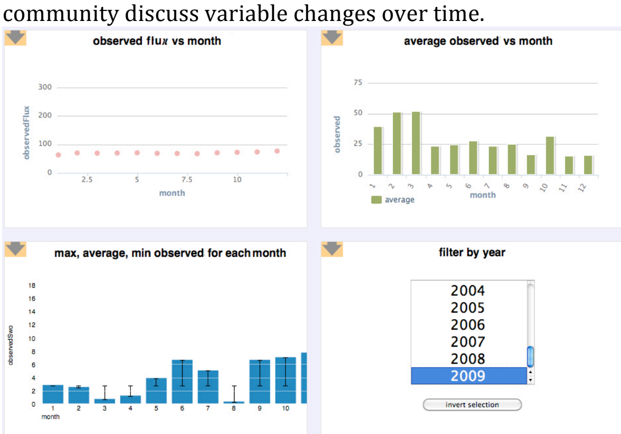

Figure 5 – Example VisDeck dashboard layout

The four widgets shown in Figure 5 demonstrate example presentations of watershed quality-related data: timelines of change such as change in precipitation flux, monthly values by year such as cumulative river discharge, and statistical values of critical variables like bird migration counts.

4.3 Content Integration and Management

As the community supporting a watershed council thrives through modeling use and visualization of model inputs, process, and outputs, the community begins to know the story of their watershed and builds content that can help share that story with others. Content becomes a valuable organizational asset for integration into watershed quality actions. As content asset values grow, content management processes become more valuable as well.

CEV Blackfish provides a content management system that has years of evolution through supporting large research initiatives at the University of Washington. The WsP can implement a Blackfish system for any watershed council to use to maximize informational assets and make them available for end-user products of interest within the community.

As CEV developers describe their support role in integration and management:

> The Center for Environmental Visualization promotes new information technologies and advanced interfaces which integrate ocean research with geo-science education. CEV combines environmental modeling with applied technologies such as Scientific Visualization, Science Illustration, Graphic Design and Web Development. Our efforts include innovative combinations of technologies that allow learners to interact with near real-time data using highly visual, exploratory interfaces based on ocean science.

With help from us at the WsP, CEV Blackfish integrated server software services can be applied to support watershed council users with the same contribution of support applied the ocean research community.

4.4 The Content Store

As the CEV Blackfish system is used to generate end products to encourage community support and personal action on behalf of watershed quality, content is tagged and described in ways that promote serendipitous discovery by casual investigators. The content store provides repository services and search facilities for exploring content that has been used in promotional and planning contexts.

By externalizing the content store from the integration and management services, content can be reused by other Web-based processes through time-tested techniques for sharing content (standardized querying, metadata tagging, taxonomic and thematic organization, and advanced search). Upon building social community bridges across watershed council and waterkeeper alliance organizations, sharing content becomes facilitated through a shared content store schema.

5 Conclusion

Through participation in adaptive WsP packaging of the software tools shown in Figure 3, the WsP can help watershed councils and waterkeeper alliances make better decisions as they educate their communities. Phase II work will allow the WsP to work closely with software developers who can facilitate best coding practices while the WsP focuses on best iterations of the software for the needs of watershed councils, waterkeeper alliances, and the roles in the communities they serve that seem best integrated with watershed quality.

The WsP spent a significant effort getting to know the community of watershed councils and their constituents it wishes to continue serving beyond the efforts of Phase I activities. Building social ties that help members of the community trust and understand points of view from other members of the community is critical to building support for local watershed council activity. The true value of WsP contribution may be the iterative social and software development processes by which it incrementally improves effectiveness in building personal action and conservation awareness within a community that lives within natural watershed boundaries.

Phase II is just the next phase of work associated with suggested goals and outcomes that are a by-product of community suggestions and shared actions. Continued outreach to the communities we wish to serve is guaranteed to be a requirement for success. As Phase II efforts progress through our iterative work processes, future papers like those prepared for the International Aquarium Congress will continue to document the path towards opening up watershed quality assessment and planning activities to each interested citizen. We hope that empowering those citizens will continue to make a tangible difference.
The success of partnering with the best organizations with which to improve effectiveness will depend upon the impact the WsP can make in negotiating better shared attempts. By offering software development and visual literacy support through software, we hope to continue to have a valued seat at the community efforts of improved watershed quality for all watersheds.

Acknowledgments

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