Pesticide use practices and surface water loading in the Zollner Creek Watershed
Progress Report to the Oregon Processed Vegetable Commission

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This report describes progress in our collaboration with the Marion SWCD, NRCS, Wilco, and others to refine the USDA ARS model SWAT as a decision aid for producers in the Zollner Creek watershed to evaluate alternative site-specific land use practices that meet both production and environmental protection goals with an emphasis on water quality.

Over 30 years of surface water monitoring conducted by federal and state agencies have identified pesticides as a concern in the Zollner Creek watershed. The US Geological Survey (USGS) has conducted monitoring activities in the Zollner Creek watershed from 1993-2008 and resumed monitoring in October 2011 as part of the National Water Quality Assessment (NAWQA) program. The USGS NAWQA program began in the early 1990s in order to assess the quality of surface and ground water in the United States, trends in the quality of surface and ground waters and the impacts of natural features and anthropogenic activities on the quality of surface and ground waters. During this time, a variety of pesticides were detected at a high frequency with several detections approaching or exceeding water quality standards. Beginning in 2005, the Oregon Department of Environmental Quality (ODEQ) initiated monitoring in the Pudding River basin as part of the Pesticide Stewardship Partnership (PSP) program including monitoring within the Zollner Creek watershed. The PSP program was developed to identify water quality issues related to pesticides, share the monitoring data with local stakeholders, identify and implement mitigation strategies, and assesses trends in pesticide related water quality issues. As with the NAWQA monitoring, a variety of pesticides were detected at high frequencies with several detections approaching or exceeding water quality standards. The high frequency of detection and the levels of pesticides found in the Zollner Creek watershed have led to a continued interest in the connection between land management practices in the watershed and surface water pesticide loading.

Recent USGS and ODEQ pesticide monitoring in the Zollner Creek watershed has shown a decrease in the detection frequency and levels of many of the pesticides that led to the concern regarding water quality in the watershed. The decrease in detection frequency has led some to conclude that the pesticides were no longer used for pest control in the watershed. However, in addition to the USGS and ODEQ surface water pesticide monitoring conducted in the Zollner Creek watershed, we conducted continuous pesticide monitoring utilizing passive sampling techniques from June 2010 to October 2011 (Figure 1). The USGS and ODEQ sampling methods relied on fixed frequency grab sampling techniques that provide a snapshot of pesticide concentrations in surface waters at the moment that the samples are collected. Characterizing pesticide surface water contamination via grab sampling techniques can be very difficult due to high temporal variation in pesticide concentrations, the large volume of samples that is required to collect enough of the compounds to meet the instrument levels of detection in order to quantify pesticides found, and the large number of samples that would be required to capture the temporal variability of pesticides in surface waters. Passive sampling offers some advantages over tradition grab sampling techniques regarding these challenges. Passive sampling devices can be deployed in surface waters for extended periods of time during which they can sequester and concentrate freely dissolved pesticides, capturing the episodic fluctuations in pesticide concentrations. This however can also be a limitation of passive sampling techniques as the concentrations determined by this method normalize the pesticide concentrations over the duration of the deployment. Another advantage of passive sampling is that they can detect lower levels of pesticides in the water column due to the fact that they concentrate low levels of pesticides over the entire period of deployment thus reducing the limits of detection. One example of the passive sampling techniques to detect lower levels of pesticides in surface waters is the levels of the organophosphate insecticide chlorpyrifos. During the continuous passive sampling period of June 2010 to October 2011, ODEQ conducted 6 grab sampling events. ODEQ did not detect chlorpyrifos in any of the samples collected at any of the sampling locations during this time period whereas passive sampling devices detected chlorpyrifos in 100% of the samples collected in Zollner Creek watershed during the same period. Given the advantages of passive sampling techniques, we utilized passive samplers to assess the temporal patterns in pesticide levels in the Zollner Creek watershed on a continuously for over a year.

Monitoring alone provides limited insight into the connection between land management practices and surface water pesticide loading. Pesticide surface water loading is highly variable and is influenced by pesticide use patterns and application methods (i.e., initial distribution on the landscape), pesticide properties that influence environmental fate, as well as landscape/land management, edaphic, and climatic factors. Surface water monitoring data indicates only the presence of pesticides in surface waters and does not provide insight into the specific conditions or factors that led to the off-site transport. Pesticide fate models can provide a means to better understand the connection between land management practices and pesticides identified in surface waters through monitoring. One such pesticide fate model is the Soil and Water Assessment Tool (SWAT).

SWAT is a watershed scale model developed by the USDA Agricultural Research Service (ARS) to evaluate the impacts of land management practices on water, sediment and chemical yields in large, variable basins. SWAT is a physically based process model that utilizes a systems approach to capture the collective expertise of ARS across multiple disciplines. SWAT uses physical characteristics of the landscape including land use/land cover, soil types and topography along with weather data and physical chemical properties of compounds to perform mathematical simulations of the processes that dictate routing of water, chemicals and sediment. SWAT operates continuously on a daily time step in order to account for the spatial and temporal variation in the factors that influence the routing of water, chemicals and sediment. SWAT has been utilized both nationally and internationally to assess water balance and non-point source pollution issues at the watershed scale. The widespread applicability of SWAT has lead it to be incorporated in US EPA Total Maximum Daily Load (TMDL) models, considered to be used to assess mitigation measures under the European Union Water Framework Directive (WFD), be utilized as one of two models accepted for use in the USDA Conservation Effects Assessment Project (CEAP), and to be utilized in nearly 1500 peer reviewed studies. Two applications in which the SWAT model has been shown to be a beneficial tool is in the evaluation of critical source areas of non-point source pollution and evaluation of mitigation measures to reduce non-point source loading. Based on this wide spread application and the capabilities of the model, we have chosen to utilize SWAT to assess pesticide surface water loading in the Zollner Creek watershed.

In order to utilize the SWAT model, detailed information on climatic variables, soil characteristics, land use and land management data, hydrologic data, and physical characteristics of the watershed such as topography are required to parameterize the model. Much of the required model input data can be found organized in geographic information system (GIS) datasets. One key benefit of the SWAT model is the GIS interface, ArcSWAT, which has been developed in order to use the data captured in GIS datasets to parameterize the model. In typical applications of SWAT, freely available GIS datasets from the USGS National Map program, USGS National Hydrography Dataset, and the USDA Natural Resources Conservation Service Geospatial Data Gateway. In many of applications of the SWAT model in the US, datasets from these sources are adequate to parameterize the model due to limited heterogeneity of land uses within the watersheds being modeled.

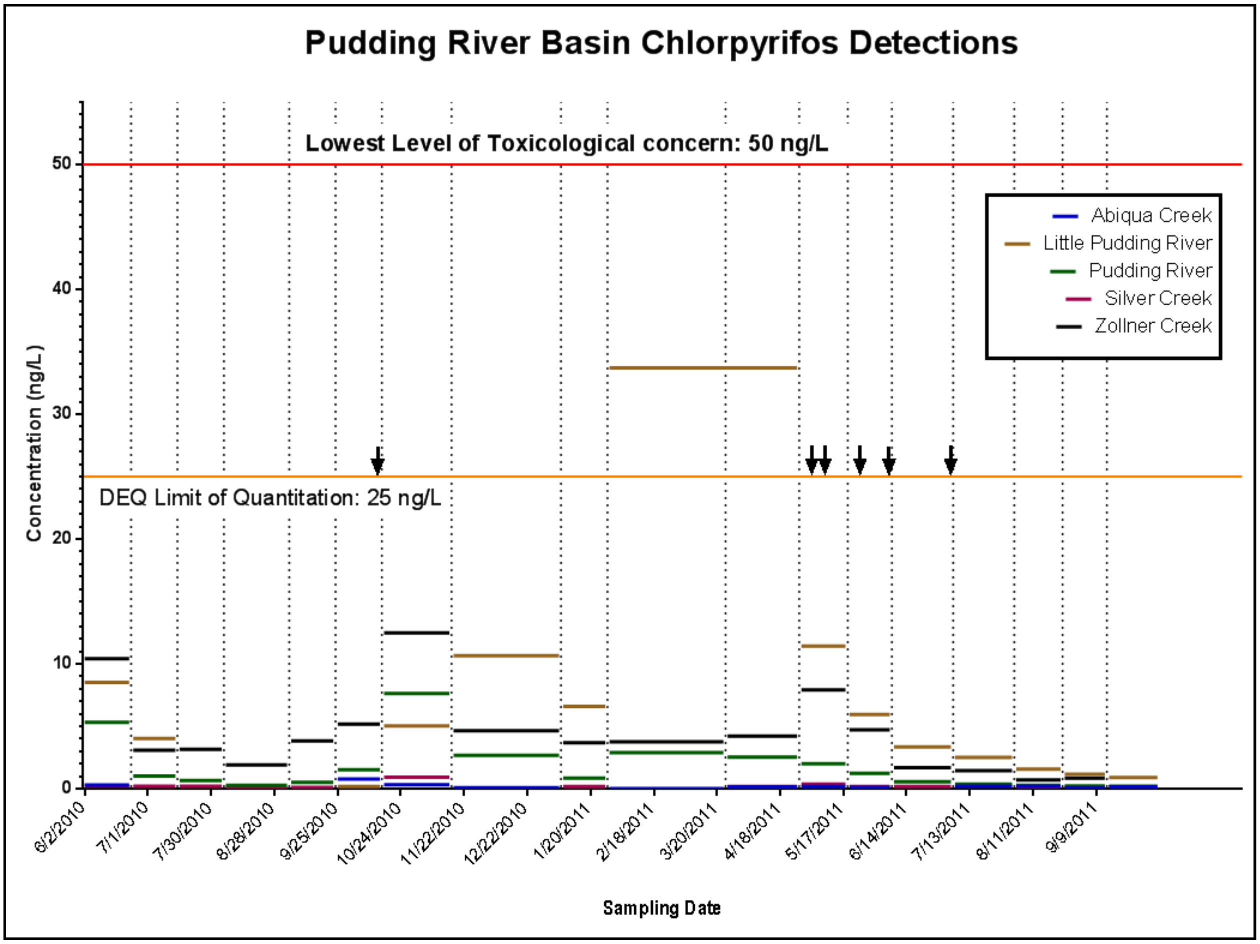

Figure 1. Chlorpyrifos concentrations (ng/L) detected during continuous passive sampling between June 2010 and October 2011 in various surface waters of the Pudding River basin. Horizontal lines represent the time weighted average concentration determined from the use of passive sampling devices during the sampling period defined by the dashed vertical lines. All levels of chlorpyrifos detected during the sampling campaign were below the lowest level of toxicological concern for aquatic invertebrates of 50 ng/L shown by the red line. The orange horizontal line shows the ODEQ limit of quantitation for chlorpyrifos in samples collected during this time period of 25 ng/L. ODEQ sampling events are indicated by black arrows on the dates that samples were collected. Of the ODEQ samples collected during the time period, no chlorpyrifos concentrations were reported above the limit of quantitation.

However, the Zollner Creek watershed is a highly variable agricultural watershed. Based on evaluation of the USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) data, the Zollner Creek watershed is 91% agricultural areas with 43 different agricultural land uses identified. In order to organize the data, a database of individual field units in the Zollner Creek watershed was developed. A GIS layer of individual units was created utilizing FSA National Agricultural Imagery Program (NAIP) aerial imagery data sets for the Marion County, OR area for 2009 and 2011. A total of 893 individual units were identified from the NAIP aerial imagery within the Zollner Creek watershed boundaries. These units included individual field boundaries, developed areas (housing, commercial areas, containers nurseries and other production facilities), open water (stream channel and farm ponds) and forested areas (not including orchards, nursery or Christmas tree production areas). Based on evaluation of NAIP imagery, 191 units were identified as developed areas, 68 as forested areas, and 12 as open water. The remaining 622 units represented individual fields utilized for agricultural production. We have begun to collect and organize land use and agronomic practice data for these field units in the Zollner Creek watershed in order to refine SWAT model parameterization.

One of the main sources of uncertainty in pesticide fate modeling is the lack of understanding of pesticide use patterns. In order to refine our understanding of pesticide use patterns in the Zollner Creek watershed, it was first necessary to accurately identify the crops being grown in the 622 units that were defined from the aerial imagery. Closer examination of the CDL datasets allowed us to tentatively identify the land use in all but 167 field units. Since the CDL data is the most refined publically available data, the only way to further refine our understanding of land use and land management in the watershed was to utilize local knowledge of the system in order to parameterize the model.

In order to address pesticide related water quality concerns, it is necessary to link land management activities to pesticide monitoring data. Hydrologic and pesticide fate models such as SWAT can be beneficial tools in evaluating this link. The model will be most useful in assessing the processes and routes of pesticide movement when we are able to reduce the uncertainty in input data required to parameterize the model through the incorporation of local knowledge of the study system. With an understanding of pesticide fate processes derived from model evaluations, we can begin to utilize this understanding to assess alternative practices or mitigation measures that can be utilized to limit off-site movement of pesticides. The Zollner Creek watershed provides a unique case in which to test the applicability of the SWAT model and continuous pesticide monitoring to assess the relationship between land management and water quality concerns. Through the completion of the goals listed below, we hope to utilize this project as a demonstration of a methodology through which to evaluate pesticide water quality concerns and provide growers with a decision aid to meet both production and environmental protection goals.

The goals of this project are:

1. A better understanding of the relationship between the land use setting, agronomic practices and mitigation measures, and pesticide surface water loading in the Zollner Creek watershed.

2. Adoption of new, or demonstration of existing, agronomic practices and mitigation measures that meet both production and environmental protection goals.

3. A methodology for using SWAT as a decision aid in evaluating alternative site-specific land use practices in Oregon watersheds.

To achieve these goals we propose the following objectives:

- Work with collaborators to assemble a team knowledgeable of land use practices in the Zollner creek watershed; assemble key land use data; with local knowledge and data, evaluate the feasibility of using SWAT to describe the relationship between land use practices and/or settings and pesticide surface water loading in the Zollner Creek watershed.

- Use SWAT, vetted by producers and their advisors, as a decision aid to evaluate alternative agronomic practices and mitigation measures with regard to their ability to meet both production and environmental protection goals.

- Conduct outreach efforts that demonstrate the utility of SWAT as a decision aid to evaluate alternative agronomic practices and mitigation measures with regard to their ability to meet both production and environmental protection goals.

- Evaluate the transferability of SWAT as a decision aid in evaluating alternative agronomic practices and mitigation measures in other Oregon watersheds.

Progress towards objectives:

- Objective 1.
  - We began collaboration with Wilco in Mt Angel beginning in June 2012. We worked with agronomists that consult with growers in the watershed to identify land uses in the field units defined from the aerial imagery. A tremendous amount of time and effort was required in order to collect and organize the data that was obtained. As of December 2013, through collaboration with the Wilco, we have been able to identify the land uses in field units representing 69% of the Zollner Creek watershed area during the period of 2010-2011 (see Figure 2).

  - We are continuing to collaborate with the Wilco and the Marion Soil and Water Conservation District in order to identify and contact the growers that farm the remaining 31% of the field units where the land use is not known during the period of 2010-2011.

  - For field units for which we are unable to obtain local knowledge of the specific land use during the 2010-2011 time period, we are working on developing a more refined estimate of the land use based on a combination of the CDL data, aerial imagery, and local knowledge derived from our collaboration with the Wilco agronomists. For field units with an undefined land use, we will evaluate the CDL data for each field unit. The CDL defined land use will then be visually compared with aerial imagery of fields with the same land use defined through our collaboration with the Wilco agronomists in order to verify the land use.

  - Through collaboration with the Wilco, we have been able to produce representative crop management timelines for 17 crops grown in the Zollner Creek watershed during the 2010-2011 time period.

- Objective 2
  - To date we have focused on completing Objective 1. Utilizing local knowledge in model parameterization can reduce the level of uncertainty in model estimations and create a more useful tool for the grower community. Currently we are working on parameterizing the SWAT model with the local knowledge that we have obtained through our collaborations while attempting to gather the remaining land use and land management data. We will be prepared to present pesticide modeling results at the OPVC grower meeting in January. We will also present a demonstration of SWAT modeling scenarios evaluating alternative management strategies and mitigation measures.

  - In weeks following the OPVC meeting we will meet producers and their advisors to discuss how best to use SWAT as a decision aid to evaluate alternative agronomic practices and mitigation measures with regard to their ability to meet both production and environmental protection goals.

  - Following this evaluation of SWAT we will conduct outreach efforts that demonstrate the utility of SWAT as a decision aid to evaluate alternative agronomic practices and mitigation measures with regard to their ability to meet both production and environmental protection goals.

- Objective 3
  - Considering feedback from outreach efforts we will refine our methodology for using SWAT as a decision aid in evaluating alternative site-specific land use practices in Oregon watersheds and evaluate the transferability of SWAT as a decision aid in evaluating alternative agronomic practices and mitigation measures in other Oregon watersheds.

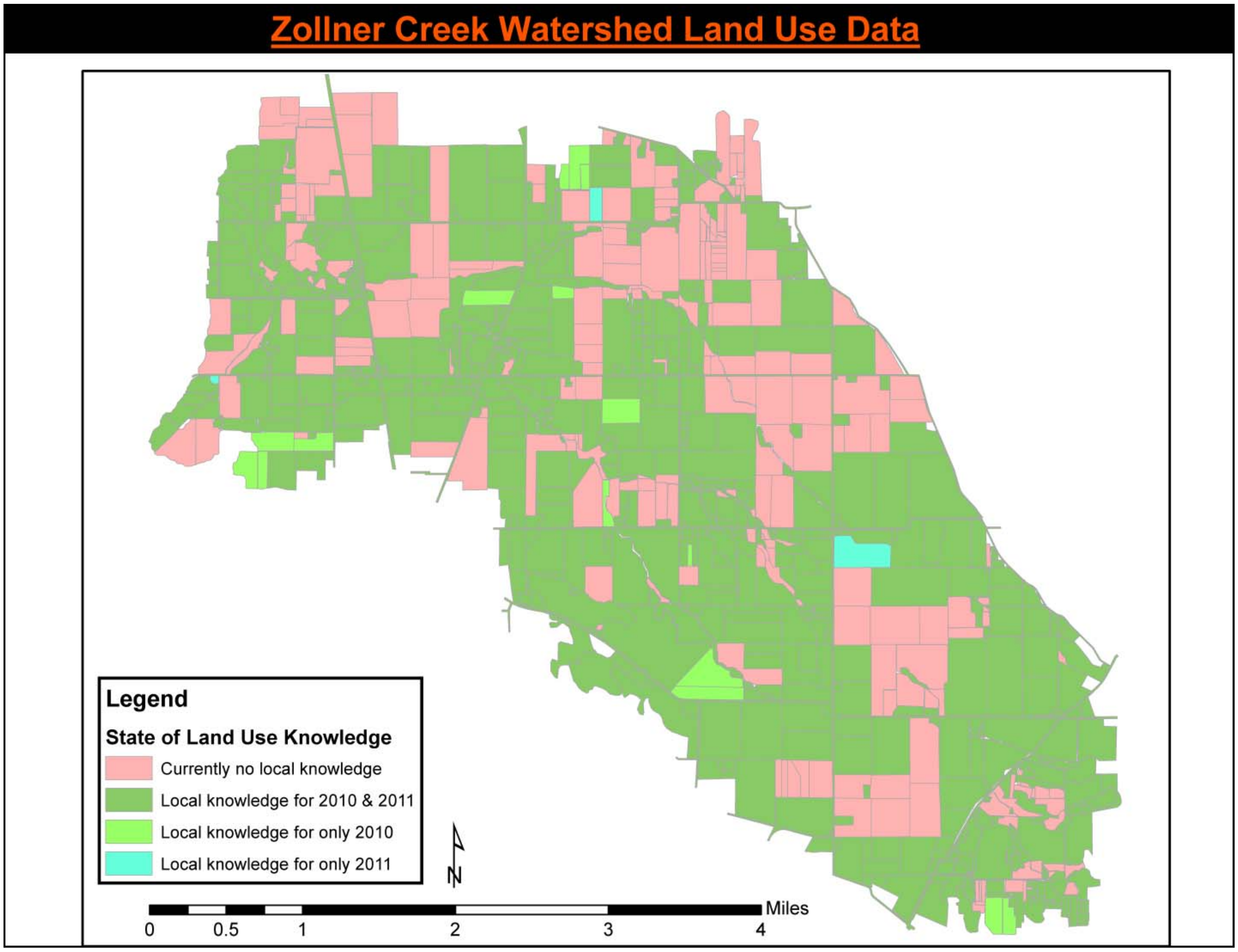

Figure 2. Map of the field units defined from NAIP aerial imagery in the Zollner Creek watershed and the areas of known land uses following initial collaboration with the Wilco agronomists.