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Data Quality Report for the Alsea Watershed Study Revisited Water Quality Measurements

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Data Quality Report for the Alsea Watershed Study Revisited Water Quality Measurements

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Prepared by

Terry Bousquet (Retired)
NCASI
Corvallis, Oregon

Acknowledgments

Several collaborating organizations known as the Oregon State University Watersheds Research Cooperative participated in the Alsea Watershed Study Revisited, which occurred in the Oregon Coast Range. During most of this study, Needle Branch sampling sites were located on Plum Creek Timber Company property, now owned by Weyerhaeuser Company. Timber harvest schedules and land management decisions were managed by Jeff Light of Plum Creek Timber Company. Deer Creek and Flynn Creek were accessed on US Department of Agriculture (USDA) Forest Service land with permission from the US Forest Service.

For more information about this report, contact:

Dr. Ashley Coble
Senior Research Scientist
NCASI
2438 NW Professional Drive
Corvallis, OR 97330
(541) 752-8801
acoble@ncasi.org

Dr. Darren Miller
Vice President - Forestry Programs
NCASI
(662) 325-0754
dmiller@ncasi.org

To request printed copies of this report, contact NCASI at publications@ncasi.org or (352) 244-0900.

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STUDY COLLABORATORS

The collaborators involved in collecting and reviewing water quality data for the Alsea Watershed Study Revisited who contributed to this report are as follows.

Alsea Watershed Study Revisited Water Quality Collaborators

Collaborator	Responsibilities
Plum Creek Timber Company	
Jeff Light	Needle Branch property access, project coordination, harvest schedules, and stream temperature monitoring and analysis
National Council for Air and Stream Improvement, Inc. (NCASI)	
Dr. George Ice	NCASI project coordination (2005-2012) and dissolved oxygen data analysis
Dr. Robert Danehy	NCASI project coordination (2012-2016)
Terry Bousquet	Database development and coordination, dissolved oxygen and nutrient data validation
Diana Cook, Jan Napack, and David Campbell	Nutrient analyses and data evaluation
Dr. Jeff Louch	Herbicide study
Oregon State University, Department of Forest Engineering	
Dr. Arne Skaugset and Dr. Kevin Bladen	Oregon State University project coordination
Cody Hale, David Leer, and Tina Garland	Instrument deployment and data collection from turbidity threshold sampling data loggers and dissolved oxygen probes, sample collection for nutrients and sediments
Amy Simmons	Database management, laboratory turbidity, and sediment analysis management and data validation
Alex Irving, Dr. Jeff Hatten	Turbidity threshold sampling data evaluations and sediment data analysis
Dr. Catalina Segura	Stream discharge evaluation
Dr. Nicholas Cook and Jeff Light	Turbidity threshold sampling temperature data evaluations and temperature data analysis
Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship	
Dr. John Stednick and Matthew Menk	Stage data evaluation and discharge determinations

Elements of the 2006 ***Quality Assurance Project Plan to Support the Alsea Watershed Study Revisited*** were used to assess data quality, which is available at: https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf

The ***Quality Assurance Project Plan to Support the Alsea Watershed Study Revisited*** was prepared by Terry Bousquet, Project Leader, NCASI, Corvallis, Oregon, to partially fulfill internship requirements for the Oregon State University Professional Science Master's degree in Environmental Sciences program.

EXECUTIVE SUMMARY

PROJECT OVERVIEW

The Alsea Watershed Study Revisited project, carried out in the Oregon Coast Range, US, began in October 2005. The original study from 1959 to 1965 measured historic effects of forest management on aquatic systems. The purpose of the Alsea Watershed Study Revisited project was to compare the effects of current forest practices with those practiced before the advent of the Oregon Forest Practices Act (first passed in 1971). The Alsea Watershed Study was one of the first paired watershed studies to simultaneously examine effects of forest management practices on flow, water quality, salmonid habitat, and fish. Three small watersheds (Needle Branch, 175 acres; Deer Creek, 750 acres; and Flynn Creek, 500 acres) were monitored before and after treatment. Alsea Watershed Study Revisited focused on Needle Branch as the treated watershed and Flynn Creek as an undisturbed, control watershed. Deer Creek was not included in the project except as a gauging station. The upper watershed of Needle Branch was harvested using 2009 forest practices, which followed 3 years of pretreatment study and then 4 years of posttreatment study. Phase 2 harvest of the lower watershed began in September 2014 with 3 years of postharvest data collection planned.

Water quality parameters collected as part of this study included stage to determine discharge, suspended sediment, stream temperature, dissolved oxygen, and select nutrients. One advantage of watershed studies is that they provide opportunities for additional work with the benefit of existing and ongoing data sets. As such, the National Council for Air and Stream Improvement, Inc., Forest Watershed Task Group took advantage of the Alsea data set to conduct a study evaluating the extent of herbicide transport to Needle Branch after aerial application. The herbicide application in 2010 followed a timber harvest of the upper Needle Branch as part of the broader study. As part of the herbicide data assessment, several stage data gaps were identified that facilitated an overall data quality review for the Alsea Watershed Study Revisited project. These issues prompted a request for a full examination of data quality for the Alsea Watershed Study Revisited project. One goal of the Alsea Watershed Study Revisited project was to make data available to other researchers; therefore, a systematic and comprehensive evaluation of data quality was necessary prior to releasing any data to collaborators or other data users.

DATA QUALITY SUMMARY AND RECOMMENDATIONS

Data quality for each parameter and each watershed was assessed and characterized for data completeness, validity, and compliance with quality control specifications. Validation and quality control assessment procedures differed for each water quality data parameter. High-quality data have very few data gaps, meet validation criteria (e.g., stage matches field measurements, or data are within control charts), and meet prescribed quality control measures (e.g., blanks, control spikes). Data are of low quality if there are significant data gaps, data cannot be validated, or there are analytical problems. Data validated with charting or other assessment techniques are considered validated. Parameters of unknown or unreliable data quality are so noted in the synopsis and associated appendices. The following is a brief summary of data quality for the Alsea Watershed Study Revisited study:

- Most water quality data collected in the main study were complete and of good to high quality (e.g., sediment, nutrients, and dissolved oxygen).
- Issues related to flow data may create challenges for analyses of those data in conjunction with other parameters (e.g., estimation of load vs. concentration).

- The gap in flow data during the 2010-2011 winter is also unfortunate and directly affects analyses of flow, suspended sediment, turbidity, and nutrient loads. This created a gap in the continuous record and, although course approximations through rating course reconstruction may be possible for flow data, the lack of samples for turbidity and suspended sediment is problematic. This gap may also limit statistical approaches available to researchers and, at the least, reduce winter sample sizes after the first timber harvest.
- Issues associated with the herbicide study are unfortunate, but while they limit the analyses to some degree, the overall data set is unique and robust. Well-developed publication products are possible.
- The weir at the control watershed is a problem. Reconstruction of flow regime through various methods is necessary, and those approximations may or may not be adequate for various analyses.
- The temperature equipment malfunctions in 2007 limit not only spatial assessment for that year but also long-term timelines. There were still four instruments for before and after harvest but only at the weir sites.
- Overall, planned publication products should be able to be completed with data sets that can be developed with reconstructed flow regimes. Clear descriptions of those data adjustments are characterized in Appendix B1.
- Complete flow and temperature data sets are valuable to aquatic biology researchers, and effects on those analyses depend on the directions those researchers pursue.

Menk and Stednick (Appendix B1) made several recommendations to improve stream flow measurements, to facilitate data management moving forward, and to utilize and maintain individual gauging stations.

SOMMAIRE

APERÇU DU PROJET

Le projet d'étude revisitée du bassin versant Alsea, réalisé dans la chaîne côtière de l'Oregon aux États-Unis, a débuté en octobre 2005. L'étude originale réalisée entre 1959 et 1965 mesurait les effets historiques de l'aménagement des forêts sur les systèmes aquatiques. Le but du projet d'étude revisitée du bassin versant Alsea était de comparer les effets des pratiques forestières actuelles aux effets des pratiques appliquées avant l'adoption de la *Loi sur les pratiques forestières de l'Oregon* (*Oregon Forest Practices Act*) en 1971. L'étude du bassin versant Alsea était l'une des premières études appariées sur les bassins versants qui examinaient simultanément les effets des pratiques d'aménagement forestier sur le débit, la qualité de l'eau, l'habitat des salmonidés et le poisson. Elle portait sur trois petits bassins versants (Needle Branch, 175 acres; Deer Creek, 750 acres; and Flynn Creek, 500 acres) étudiés avant et après traitement. Dans l'étude revisitée, on a choisi Needle Branch pour être le bassin versant traité et Flynn Creek comme bassin versant témoin non perturbé. Deer Creek n'a pas été inclus dans le projet, mais a été utilisé comme station hydrométrique. La partie supérieure du bassin versant Needle Branch a été récoltée en appliquant les pratiques forestières en vigueur en 2009. La récolte a eu lieu après 3 ans d'une étude pré-traitement, puis a été suivie d'une étude post-traitement de 4 ans. La récolte de la partie inférieure du bassin versant (Phase 2) a débuté en septembre 2014 avec une collecte prévue de données post-traitement de 3 ans.

Les paramètres de qualité d'eau recueillis dans le cadre de cette étude incluaient le niveau de l'eau pour mesurer son écoulement, les sédiments en suspension, la température du cours d'eau, l'oxygène dissous et certains nutriments sélectionnés. Un des avantages des études de bassin versant est la possibilité de réaliser des travaux additionnels en tirant profit de données existantes et de données recueillies sur une base continue. Ainsi, le Groupe de travail sur les bassins versants forestiers du *National Council for Air and Stream Improvement, Inc.*, a tiré profit de l'ensemble de données recueillies dans le bassin versant Alsea pour réaliser une étude qui évaluait l'étendue du transport d'un herbicide dans le bassin versant Needle Branch après une application par voie aérienne. L'herbicide a été appliqué en 2010 après une récolte du bois dans la partie supérieure de Needle Branch dans le cadre d'une étude plus large. Lors de l'évaluation des données sur l'herbicide, on a identifié plusieurs données manquantes sur le niveau de l'eau qui ont facilité une analyse globale de la qualité des données pour le projet d'étude revisitée du bassin versant Alsea. Ces lacunes ont mené à une demande d'examen complet de la qualité des données pour le projet d'étude revisitée du bassin versant Alsea. Un des objectifs du projet d'étude revisitée du bassin versant Alsea était de mettre les données à la disposition d'autres chercheurs. C'est pourquoi, il était nécessaire d'avoir une évaluation complète et systématique de la qualité des données avant de publier quelle que donnée que ce soit aux collaborateurs et autres utilisateurs des données.

APERÇU DE LA QUALITÉ DES DONNÉES ET RECOMMANDATIONS

On a évalué et caractérisé la qualité des données de chaque paramètre et de chaque bassin versant en fonction de leur complétude, validité et conformité aux normes de contrôle de la qualité. Les procédures de validation et d'évaluation du contrôle de la qualité étaient différentes pour chaque paramètre de données sur la qualité de l'eau. Dans les données de grande qualité, il y a eu très peu de données manquantes. De plus, elles respectaient les critères de validation (p. ex. le niveau de l'eau correspondait aux mesures de terrain, ou les données étaient à l'intérieur des limites des cartes de contrôle) et respectaient les mesures de contrôle de qualité spécifiées (p. ex. les blancs, les échantillons de contrôle enrichis. Les données étaient de faible qualité s'il y avait beaucoup de données manquantes, s’il n’était pas possible de valider les données ou s’il y avait des problèmes analytiques. On a considéré que les données validées par la cartographie ou une autre technique d’évaluation étaient validées. Les paramètres dont les données étaient de qualité inconnue ou douteuse étaient notés dans le synopsis et annexes associées. Voici un bref résumé sur la qualité des données pour l’étude revisitée du bassin versant Alsea :

- La plupart des données sur la qualité de l’eau recueillies pour l’étude principale étaient complètes et de bonne qualité ou de grande qualité (p. ex. sédiments, nutriments et oxygène dissous).
- Des problèmes reliés aux données sur le débit pourraient poser des défis lors des analyses de ces données conjointement avec d’autres paramètres (p. ex. estimation de la charge vs la concentration).
- Le manque de données sur le débit à l’hiver 2010-2011 est malheureux et a un effet direct sur les analyses du débit, de la concentration des sédiments en suspension, de la turbidité et des charges en nutriment. Ce problème a créé une discontinuité dans l’enregistrement continu des données et, bien qu’il soit possible d’obtenir des approximations à l’aide d’une reconstruction du régime d’écoulement pour déterminer le débit, le manque d’échantillons pour déterminer la turbidité et la concentration des sédiments en suspension est problématique. Ce manque de données peut aussi réduire le nombre d’approches statistiques à la disposition des chercheurs et entraîner une réduction de la taille des échantillons analysés pour l’hiver après la première récolte de bois.
- Les problèmes associés à l’étude sur l’herbicide sont aussi malheureux mais, bien qu’ils limitent les analyses dans une certaine mesure, l’ensemble de données est globalement unique et robuste. Il sera possible de bien développer des produits pour publication.
- Le déversoir dans le bassin versant qui sert de contrôle constitue un problème. On doit reconstruire le régime d’écoulement à l’aide de diverses méthodes et ces approximations peuvent être ou ne pas être adéquates pour effectuer les différentes analyses.
- Le fonctionnement défectueux de l’équipement de mesure de la température en 2007 restreint non seulement l’évaluation spatiale pour cette année-là, mais aussi celles à long terme. Quatre instruments sont toutefois demeurés en place avant et après la récolte, mais seulement sur le site de leur déversoir.
- Dans l’ensemble, il devrait être possible de générer les produits de publication prévus avec des ensembles de données développés avec des régimes d’écoulement reconstruits. Des descriptions claires de ces ajustements dans les données sont présentées à l’Annexe B1.
- Des ensembles complets de données sur le débit et la température sont précieux pour les chercheurs de biologie aquatique et les incidences sur les analyses de ces paramètres dépendent des orientations prises par ces chercheurs.

Menk et Stednick (Annexe B1) ont fait plusieurs recommandations pour améliorer les mesures du débit d’un cours d’eau, faciliter la gestion des données dans le futur, ainsi qu’utiliser et maintenir des stations hydrométriques individuelles.

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DATA QUALITY REPORT FOR THE ALSEA WATERSHED STUDY REVISITED
WATER QUALITY MEASUREMENTS

TECHNICAL BULLETIN NO. 1093
APRIL 2025

ABSTRACT

The original Alsea Watershed study (1959 to 1965) measured the effects of historical forest management practices on aquatic systems, and the results of this study led to the establishment of rules to protect water quality in the Oregon Forest Practices Act in 1971. The original Alsea Watershed Study was one of the first paired watershed studies to simultaneously examine the effects of forest management practices on discharge, water quality, aquatic ecosystem characteristics, and fish. The Alsea Watershed Study Revisited project (began in October 2005) was designed to compare the effects of current forest practices with those historical practices and included many of the same parameters quantified in the original study. All three small watersheds (Needle Branch (clearcut), 175 acres; Deer Creek (patch cut), 750 acres; and Flynn Creek (reference), 500 acres) included in the original study were also monitored in the revisit with only Needle Branch harvested, Flynn Creek remaining a reference. The upper watershed of Needle Branch was harvested using forest practices that were current in 2009, which followed 3 years of pretreatment and then 4 years of posttreatment study. Phase 2 harvest of the lower watershed began in September 2014 with 3 years of postharvest data collection planned as of 2016. We completed a systematic and comprehensive evaluation of data quality prior to releasing any data to collaborators or other data users, and the results of this analysis are described in detail in this report. Here, we provide an overview of the data quality for water quality parameters collected in this study: stage to determine discharge, suspended sediment, turbidity, stream temperature, dissolved oxygen, and nutrients (nitrogen and phosphorus species). This report also describes herbicide data assessment following a silvicultural herbicide application in Needle Branch in 2010.

KEYWORDS: Water quality, Forest harvest, riparian buffers, discharge, turbidity, suspended sediment, temperature, dissolved oxygen, nutrients, herbicide, Pacific Northwest

RELATED NCASI PUBLICATIONS

National Council for Air and Stream Improvement, Inc. (NCASI). 2013. Measurement of glyphosate, imazapyr, sulfometuron methyl, and metsulfuron methyl in Needle Branch streamwater. Special Report No. 13-01. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

National Council for Air and Stream Improvement, Inc. (NCASI). 1991. The New Alsea Watershed Study. Technical Bulletin No. 602. New York, NY: National Council for Air and Stream Improvement, Inc.

Quality Assurance Project Plan (QAPP) Prepared By: Terry Bousquet, Project Leader, NCASI, Corvallis, Oregon, to partially fulfill internship requirements for the OSU Environmental Sciences Professional Science Masters Program. Available from: https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf

RAPPORT SUR LA QUALITÉ DES DONNÉES SUR LES MESURES DE QUALITÉ DE L'EAU DE L'ÉTUDE REVISITÉE DU BASSIN VERSANT ALSEA

BULLETIN TECHNIQUE N^{O} 1093
AVRIL 2025

RÉSUMÉ

L'étude originale du bassin versant Alsea (1959 à 1965) mesurait les effets des pratiques historiques d'aménagement forestier sur les systèmes aquatiques, et les résultats de cette étude ont mené à l'adoption de règles pour protéger la qualité de l'eau dans la *Loi sur les pratiques forestières de l'Oregon* (*Oregon Forest Practices Act*) en 1971. L'étude originale du bassin versant Alsea était l'une des premières études appariées sur les bassins versants qui examinaient simultanément les effets des pratiques d'aménagement forestier sur le débit, la qualité de l'eau, les caractéristiques des écosystèmes aquatiques et le poisson. Le projet d'étude revisitée du bassin versant Alsea (a commencé en octobre 2005) avait pour but de comparer les effets des pratiques forestières actuelles aux effets des pratiques historiques et portait sur bon nombre des mêmes paramètres quantifiés dans l'étude originale. Les trois petits bassins versants (Needle Branch (coupe à blanc), 175 acres; Deer Creek (coupe par trouées), 750 acres; et Flynn Creek (référence), 500 acres) qui étaient inclus dans l'étude originale ont aussi été suivis dans l'étude revisitée, mais seul Needle Branch a fait l'objet de récoltes et Flynn Creek est demeuré la référence. La partie supérieure du bassin versant Needle Branch a été récoltée en appliquant les pratiques forestières courantes en 2009. La récolte a eu lieu après 3 ans d'une étude pré-traitement, puis a été suivie d'une étude post-traitement de 4 ans. La récolte de la partie inférieure du bassin versant (Phase 2) a débuté en septembre 2014 avec une collecte prévue de données post-traitement de 3 ans (2016). Nous avons effectué une évaluation complète et systématique de la qualité des données avant de communiquer quelle que donnée que ce soit à des collaborateurs ou autres utilisateurs des données. Les résultats de cette analyse sont décrits en détail dans le présent rapport. Nous présentons un aperçu de la qualité des données pour les paramètres de qualité de l'eau mesurés dans cette étude : niveau de l'eau pour déterminer le débit, la concentration des sédiments en suspension, la turbidité, la température du cours d'eau, l'oxygène dissous et les nutriments (espèces d'azote et de phosphore). Le présent rapport décrit aussi l'évaluation des données recueillies dans une étude qui a suivi l'application d'un herbicide sylvicole dans le bassin versant Needle Branch en 2010.

MOTS-CLÉS : bandes riveraines, débit, herbicide, nord-ouest du Pacifique, nutriments, oxygène dissous, qualité de l'eau, récolte forestière, sédiments en suspension, température, turbidité

AUTRES PUBLICATIONS DU NCASI

National Council for Air and Stream Improvement, Inc. (NCASI). 2013. Mesure du glyphosate, de l'imazapyr, du sulfométuron de méthyle et du metsulfuron-méthyle dans des cours d'eau du bassin versant Needle Branch. Rapport spécial n^{o} 13-01. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc. (seuls le Résumé et la Note du Président sont en français)

National Council for Air and Stream Improvement, Inc. (NCASI). 1991. The New Alsea Watershed Study. Bulleting technique n^{o} 602. New York, NY: National Council for Air and Stream Improvement, Inc.

Plan du projet d'assurance de la qualité (PPAQ) préparé par : Terry Bousquet, chargé de projet, NCASI, Corvallis, Oregon, pour respecter partiellement les exigences du stage faisant partie du programme de maîtrise de sciences professionnelles en sciences environnementales de l'OSU.
https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf

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DATA QUALITY REPORT FOR THE ALSEA WATERSHED STUDY REVISITED WATER QUALITY MEASUREMENTS

1.0 PROJECT OVERVIEW

The Alsea Watershed Study Revisited project began in October 2005. The original study from 1959 to 1965 measured historic effects of forest management on aquatic systems. The purpose of this project was to compare the effects of current forest practices with those practiced before the advent of the Oregon Forest Practices Act (first passed in 1971). The original Alsea Watershed Study was one of the first paired watershed studies to simultaneously examine the effects of forest management practices on flow, water quality, aquatic system characteristics, and fish. Three small watersheds (Needle Branch, 175 acres; Deer Creek, 750 acres; and Flynn Creek, 500 acres) were monitored before and after treatment (forest harvest). The Alsea Watershed Study Revisited project focused on Needle Branch as the treated watershed and Flynn Creek as an undisturbed, control watershed. Deer Creek was not included in the current project, except as a gauging station. The upper watershed of Needle Branch was harvested using forest practices that were current in 2009, which followed 3 years of pretreatment and then 4 years of posttreatment study. Phase 2 harvest of the lower watershed began in September 2014 with 3 years of postharvest data collection planned as of 2016.

Water quality parameters collected as part of this study included stage to determine discharge, suspended sediment, stream temperature, dissolved oxygen, and select nutrients. Overviews of data quality for each of these parameters are included in this data quality report (see later sections and appendices). Discharge determinations developed from stage data were conducted by Matthew Menk and John Stednick, Colorado State University, and are included as Appendix B1.

One advantage of watershed studies is that they provide opportunities for additional work with the benefit of existing and ongoing data sets. As such, The National Council for Air and Stream Improvement, Inc. (NCASI) Forest Watershed Task Group took advantage of the Alsea data set to conduct a study evaluating the extent of herbicide transport to Needle Branch after aerial application. The herbicide application in 2010 followed a timber harvest of upper Needle Branch as part of the broader study. As part of the herbicide data assessment, several stage data gaps were identified that facilitated an overall data quality review for the Alsea Watershed Study Revisited project.

2.0 PROBLEM STATEMENT

Analyses of data for the Alsea herbicide application report identified several data gaps and inconsistencies with stage data (NCASI 2013). These issues prompted a request for a full examination of the quality of data collected for the Alsea Watershed Study Revisited project. One goal of the Alsea Watershed Study Revisited project was to make data available to other researchers; therefore, a systematic and comprehensive evaluation of data quality was necessary prior to releasing any data to collaborators or other data users.

3.0 VALIDATION OF WATER QUALITY DATA

The purpose of this report is to summarize the quality of water quality data developed to support the Alsea Watershed Study Revisited project and to provide supporting information for researchers when using these data. The Alsea Watershed Study Revisited project was a long-term study to evaluate water quality and biotic measures in response to timber harvest. Water quality data from various research organizations have been compiled in a database to assist researchers when interpreting results across disciplines. Therefore, it is important to assess and characterize data quality. Biological data have not been incorporated into the database and will be assessed independently by the principal investigators.

Maps showing the locations of gauging stations and synoptic sites and a table identifying main stem and tributary sites are presented in Appendix A. Macroinvertebrate assemblage and a comprehensive fish survey were also conducted but are not part of this report.

Data were generated for stage, conductivity, temperature, and turbidity parameters at the five gauging stations. The following were used to collect data: electronic data loggers programmed at 10-minute intervals; nutrient monitoring monthly at the gauging stations and monthly or quarterly at synoptic sites; suspended sediment at the gauging stations, which was determined by rising or falling turbidity levels; seasonal continuous stream temperature near the gauging stations and at selected synoptic sites; and dissolved oxygen (DO) probes measured periodically through the summer and early fall at locations adjacent to the five gauging stations. An overview of data quality for each of these parameters is presented in this synopsis, with more detailed discussions of data quality for each parameter provided in Appendices B-F.

An intensive herbicide study followed the first timber harvest in upper Needle Branch leading to the identification of gaps in stage data and prompting this evaluation. An overview of herbicide study quality control is included in Section 3.6, and a more detailed assessment is presented in Appendix G.

3.1 Stage and Discharge Data Quality

Electronic data loggers collected stage, conductivity, temperature, and turbidity measurements at five locations (Flynn Creek, Needle Branch [three locations], and Deer Creek). Discharge was a major emphasis of the project. In addition, analyses of many of the parameters, both abiotic and biotic, are strengthened with discharge data. Matthew Menk and John Stednick assessed stage and discharge data as part of their report that describes field protocols and techniques used to determine discharge from stage (Menk and Stednick 2013; Appendix B1). A copy of their report is included here as Appendix B1. A summary of the stage and discharge data quality is included in Appendix B.

The gauging stations on Flynn Creek (FCG), Deer Creek (DCG), and the lower gauging station on Needle Branch (NBL) are the same locations used in the original Alsea Watershed Study. An upper Needle Branch (NBU) gauge was added in October 2006. An H-flume was installed, and in December 2008, an additional gauging station was deployed farther upstream on Needle Branch at the NB-7 synoptic site. This site was identified as NBH, indicating the H-flume.

There were two issues with the flow data: (1) the weir at Flynn Creek captured sediment upstream, and a downstream tree caused a backup downstream of the weir (Figure 3.1); and (2) there was a 3- to 5-month gap in most of the flow records during winter 2010-2011.

Figure 3.1. Flynn Creek Weir Downstream (left panel), Upstream Down to the Weir (center panel), and from Below the Weir Upstream (right panel)

Historically, US Forest Service accounts have described a need to periodically remove fill on the upstream side of a weir (see center panel of Figure 3.1). At the weir sites, sandbags were placed on either side of the approach reach to guide flow through the weir, but note that there were surface ripples even at relatively low flow conditions. Also, as shown in the right panel of Figure 3.1, note the high alluvial bank on the right. The weir is a sediment trap. In the left panel of Figure 3.1, there are remains of a fallen tree; a larger stem had been removed. During high flows, a pool forms, backing up flow and causing deposition on the downstream side and backwatering above the weir crest. The vegetated area in the near view of the left panel in Figure 3.1 is deposited alluvium.

These depositions are long term (permanent), short term, and changing after storm events. This has led to inconsistent flow measurements and the need for multiple rating curves, which are described by Menk and Stednick (2013). Estimation quality affects the calculation of concentration data (nutrients, suspended sediment) to export loads.

Ongoing routine sampling and the intensive herbicide study continued the summer (2010) following timber harvest. Data gaps associated with the herbicide study were previously described (NCASI 2013). While all the factors behind the situation are unclear, there were staffing issues that led to a gap in collection of flow data at most of the gauging stations. Beginning October 1, 2010 at two gauges, and until March 8, 2011, for all but lower Needle Branch, there are no continuous stage data. This created a gap in discharge and turbidity and suspended sediment data sets of about 5 months.

Menk and Stednick (see Appendix B1) characterize the methods and compilation of streamflow data for each watershed, including data going back to 1992 for Deer Creek and lower Needle Branch. Although additional data were used to develop rating curves, this data quality report was prepared to characterize data quality for the Alsea Watershed Study Revisited, which was initiated in the fall of 2005, and represents data from water years 2006 to 2015.

The 10-minute stage data at Flynn Creek were determined to be of poor quality. Therefore, Flynn Creek data were predicted from Deer Creek data and were limited to daily, monthly, and annual discharge values. A discussion of missing Flynn Creek data was not included in the report by Menk and Stednick (Appendix B1). With the exception of Flynn Creek, each summary report includes a table indicating the number of days stage data were missing for each water year.

Table 3.1 summarizes the percentage of missing data annually at each site, except for FCG, during the Alsea Watershed Study Revisited, starting water year 2006. Although stage data were recorded at NBU for water year 2006, the missing data summary in the Menk and Stednick report (Appendix B1) did not indicate why these data were not used in the stage-discharge relationships. The H-flume in Needle Branch (NBH) was not installed until December 2008, early in the 2009 water year, which explains the high percentage in that year. The upper reaches on Needle Branch (NBU and NBH) had the highest incidence of missing data, likely due to low flow where the probe was exposed or debris fouling the sensor.

Table 3.1. Missing Stage Data Summary for Deer Creek (DCG), Needle Branch Lower (NBL), Needle Branch Upper (NBU), and Needle Branch H-Flume (NBH)

Water Year	Missing Data (%)			
	DCG	NBL	NBU	NBH
2006	24.93	24.11	Stage recorded	Not installed
2007	0.00	0.00	10.41	Not installed
2008	0.00	0.00	0.00	Not installed
2009	15.62	0.00	0.00	30.14
2010	0.82	0.00	4.66	12.60
2011	20.27	0.00	30.14	44.66
2012	6.56	0.00	0.55	0.00
2013	0.00	0.00	0.55	35.62
2014	0.00	0.82	6.03	0.00
2015	0.00	0.00	0.00	0.55
Overall	6.82	2.49	5.81	17.64

In Appendix B1, Menk and Stednick characterized the methods and compiled streamflow data for the five gauges. The data quality components of their report are summarized in more detail in Appendix B. Overviews of discharge data quality for each station are presented in Sections 3.1.1 to 3.1.5. Overall, these data were rated as fair for FCG, DCG, and NBL; poor for NBU; and poor to very poor for NBH. The quality of the data may create challenges in their analyses (e.g., estimation of load vs. concentration).

3.1.1 Flynn Creek (FCG)

Methods and compilation of streamflow data are summarized for FCG for water years 2009-2015 and recorded in an Excel file titled “FCG_Final_WY2009-2015.” All of the Flynn Creek (FCG) streamflow data were predicted with DCG streamflow data. Given the amount of prediction and confidence in the actual streamflow measurements, streamflow data were rated as fair (per Rantz et al. 1982a, b). Streamflow records (FCG_Final_WY2009-2015) include daily, monthly, and annual values. Streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used as a control to estimate annual water yields as affected by timber harvesting.

3.1.2 Deer Creek (DCG)

Methods and compilation of streamflow data are summarized for DCG for water years 1992-2015 and recorded in an Excel file titled “DCG_Final_WY1992-2015.” Given the amount of prediction and confidence in the actual streamflow measurements, these streamflow data were rated as fair (per Rantz et al. 1982b). Streamflow values can be used for relative comparisons among the different years and different gauging locations. These data cannot be used to estimate stationarity of annual water yields or serve as a control watershed without qualification.

As noted from the field notes, there were a few stage corrections related to debris removal or sedimentation in the pond. Thus, in these cases, higher recorded stage measurement overestimated streamflow.

3.1.3 Lower Needle Branch (NBL)

Methods and compilation of streamflow data are summarized for NBL for water years 1992-2015 and recorded in an Excel file titled "NBL_Final_WY1992-2015." Given the amount of prediction and confidence in the actual stage measurements, these streamflow data were rated as fair (per Rantz et al. 1982b). Daily streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate stationarity of annual water yields or effects of timber harvesting on streamflow metrics. A series of new recommendations have been made to improve streamflow measurement and water yield quantification from NBL.

3.1.4 Upper Needle Branch (NBU)

Methods and compilation of streamflow data are summarized for NBU (watershed area 84 acres) for water years 2007-2015 and recorded in an Excel file titled "NBU_Final_WY2007-2015." Given the amount of prediction and confidence in actual stage measurements, the streamflow data were rated as poor (per Rantz et al. 1982b). Streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate annual water yields as affected by timber harvesting. A series of new recommendations have been made to improve streamflow measurement and water yield quantification.

3.1.5 Needle Branch H-Flume (NBH)

Methods and compilation of streamflow data are summarized for NBH (watershed area 34 acres) for water years 2009-2015 and recorded in an Excel file titled "NBH_Final_WY2009-2015." There is a 3-foot Tracom H-flume installed at NBH. A lookup table was provided by the flume manufacturer, Tracom, whereby the user inputs the stage to obtain the corresponding discharge.

Given the amount of prediction and confidence in the actual stage measurements, these streamflow data were rated as poor to very poor (per Rantz et al. 1982b). Streamflow values can be used for relative comparisons among the different years and different gauging locations. These data cannot be used to estimate annual water yields as affected by timber harvesting.

3.2 Turbidity and Suspended Sediment Data Validation

Suspended sediment samples were collected at DCG, FCG, NBU, and NBL gauges. Sample collection was triggered by a turbidity threshold sampling (TTS) protocol (Eads and Lewis 2003) that involved using turbidity thresholds in conjunction with stage data to activate sample collection via a Teledyne ISCO sampler. Both turbidity and suspended sediment were measured using standard operating procedures at the Oregon State University, Department of Forest Engineering Resources & Management Forest Hydrology Laboratory (see Attachment B in Quality Assurance Project Plan available from: https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf; Hatten et al. 2018. Data were evaluated for completeness of field TTS measurements, percentage of synthesized and missing TTS turbidity data, and percentage of laboratory suspended sediment measurements that were flagged during the data validation process. Minimum and maximum of each validation parameter evaluated in each water year and the overall average are summarized in Table 3.2. A detailed quality assurance (QA)/quality control (QC) summary is presented in Appendix C.

Table 3.2. Data Validation for Turbidity and Suspended Sediment Measurements

Parameter	DCG	NBU	NBL	FCG
Turbidity				
Completeness (%)	56.0-99.5 (80.8)	38.9-98.7 (83.9)	78.0-97.5 (89.7)	50.8-94.7 (77.3)
Synthesized (%)	0-7.8 (1.4)	0-15.5 (2.1)	0-2.8 (0.8)	0-3.6 (0.9)
Missing (%)	0.5-44.0 (19.2)	1.3-61.1 (16.1)	3.4-22.0 (10.3)	5.3-49.1 (22.7)
Suspended Sediment				
Sample count (n =)	57-343 (193)	8-170 (51)	2-262 (115)	60-377 (194)
Flagged (%)	0.5-37.1 (4.9)	NR	0-12.3 (2)	0-16.4 (6.6)

The overall quality of field turbidity data for the Alsea Watershed Study Revisited was classified as good. The average percent completeness of field turbidity measurements ranged from 77.3% to 89.7% for water years 2007-2014 at the TTS sampling sites. Suspicious and erroneous field turbidity data have been removed and flagged. When only a few continuous turbidity measurements were removed, they were usually synthesized. The average percentage of synthesized field turbidity ranged from 0.8% to 2.1% for the sampling sites.

The overall quality of the suspended sediment data for the Alsea Watershed Study Revisited was classified as very high. For all the gauging stations during water years 2006-2015, there were 250 flagged samples out of 5,390 samples (4.6%). Data were flagged for suspicious suspended sediment values, high suspended sediment with corresponding low laboratory turbidity, interferences (e.g., pebbles, large debris, or insects not removed prior to weighing), field collection issues, empty samples that were submitted to the laboratory, or laboratory processing issues.

3.3 Stream Temperature Data Quality

Temperature data were collected by the TTS data logger and by placing thermistors adjacent to main gauging stations and at synoptic sites throughout each watershed. Several of the synoptic sites coincided with sites used for nutrient monitoring as shown in the maps in Appendix A. A detailed summary of the quality of these temperature data can be found in Appendix D for each water year, but this summary is incomplete pending an assessment of electronic data logger data from gauging stations and further review of the synoptic data by Drs. Bladon and Cook.

To assess thermistor data quality, the pattern of daily temperatures across a season was examined using the original half-hourly or hourly data plots from each tidbit download. Data were removed if it was obvious that an instrument was not in the water and then these data were reviewed for marked deviations from the diurnal pattern. Dewatering at the end of the low flow season (after mid-August), can be identified when stream sensors reveal a pattern similar to air temperatures (higher and lower daily maxima) rather than water temperatures.

Thermistor data that were missing were deleted or flagged and were considered suspect data as noted in the data files. For the 2006-2011 water years, more than 94% of data were considered valid.

The overall quality of stream temperature data for the Alsea Watershed Study Revisited project was classified as good but incomplete. Most invalid data deleted from the database typically represented water years when the stream site went dry or the thermistor was displaced and out of water. Table 3.3 gives an overview of the number of thermistors deployed at each site and the number of values deleted because they were not valid for water years 2006-2011.

Table 3.3. Overall Data Quality Summary for Thermistor Temperature 2006-2011

	Deer Creek	Flynn Creek	Needle Branch
Minimum deployed (WY)	1-2 (2008-2011)	12 (2009)	4 (2007)
Maximum deployed (WY)	16, 10 (2006, 2007)	25 (2011)	26 (2009)
Average deployed (2006-2011)	NA	15	14
Minimum deleted (WY)	0% (2008-2011)	0% (2008, 2009, 2010)	1% (2007)
Maximum deleted (WY)	11.2% (2007)	7% (2011)	9.7% (2006)
Average deleted (2006-2011)	5.6%	2.1%	5.4%
Deployment remarks	Deployment reduced to gauge DC-g (2008-2011) site DC un_2 (2008 and 2011)	None	Pro-V loggers used in 2007 malfunctioned, reducing the number of sites data were available
Data quality remarks	Validated	Validated	Validated

An overall assessment of temperature data quality is incomplete pending assessments of electronic data logger temperature data at each gauging station and further assessment of synoptic data being conducted by Drs. Bladon and Cook.

3.4 Dissolved Oxygen QA/QC Summary

Luminescent dissolved oxygen probes (Hach Model LDO101) and data loggers (HACH HQd Portable Meters) were deployed to determine DO concentration (mg/L), temperature (°C), atmospheric pressure (hPa), and percent DO (%DO) near the Deer Creek, Flynn Creek, and Needle Branch gauging stations. Deployment typically occurred during June through October when flows and DO levels were typically at their lowest. A detailed summary of the DO data quality is presented in Appendix E. Sampling at NBL and NBU and FCG sites occurred every year from 2007 through 2014. Probes were deployed at the NB-7 (NBH) site from 2008 through 2015. Deployment at the DCG site was discontinued after 2007. Probes were deployed at a tributary site on Flynn Creek (FC-1) in 2008.

Data were evaluated and flagged based on the criteria shown in Table 3.4. Flagging data were based on high percent DO (>103%), low DO (<1 mg/L), null values, or unusual readings or fluctuations. These data are flagged in the database so data users can assess validity. Data were only removed if it was apparent the instrument malfunctioned, such as if all three parameters showed null values.

Table 3.4. DO Data Flags

Flag	Criteria	Explanation
High %DO	%DO >103	DO at or near saturation, probe may be out of water (this represents ~2% of the existing data)
Low DO	DO <1.0	May be due to probe malfunction or flow conditions
Temperature spike	Sudden spike or erratic temperatures	Sudden spikes or erratic temperatures may mean probe is out of water
Unusual—"parameter"	Inconsistent measurements	Unexplained variations may be due to probe malfunction or flow conditions (e.g., unusual temperature or unusual DO)
Null—"parameter"	Null value recorded	Unknown problem, may be due to probe malfunction or dry water conditions

Overall, these data showed a high level of data quality with more than 94% of values at each site meeting the criteria of valid data. Table 3.5 summarizes the number of flagged measurements, percentage of flags in relation to number of measurements, and range of temperatures observed. The highest rate of data flags was observed at the NB-7 location due to a high number of low or null DO values, which would be expected in upper stream reaches where stretches often go dry in summer months. Annual assessments of data quality parameters are summarized in Appendix E, Table E5. For instrument-collected DO data, this represents a low level of censuring (see, e.g., DaSilva et al. 2013).

Table 3.5. Overall Data Quality Summary for DO

Site Location	n =	DO <1.0 mg/L or Null	DO% >103%	Temperature (°C)
NB-7 (NBH)	10,992	608 (5.5%)	3 (<0.1%)	8.1-16.5
NBU	16,035	112 (0.7%)	285 (1.8%)	7.1-18.8
NBL	17,655	459 (2.6%)	15 (0.1%)	6.2-15.5
FCG	15,557	6 (<0.1%)	238 (1.5%)	6.2-21.8
FC-1 (2008)	2,464	28 (1.1%)	0	6.0-14.6
DCG (2007)	1,743	0	3 (0.2%)	9.4-15.9

3.5 Nutrients Data QA/QC Summary

Beginning in October 2005, grab samples were collected monthly at DCG, Flynn Creek (FCG), lower Needle Branch (NBL), and upper Needle Branch (NBU) gauging stations. They were analyzed for nitrate-nitrite, ammonia, orthophosphate (OP), total phosphorus (TP), and total nitrogen (TN) or total Kjeldahl nitrogen (TKN). Beginning in November 2006, samples were also collected monthly at an additional Needle Branch synoptic site (NB-7) for the same list of nutrient parameters. In November 2007, an H flume and gauge were installed at that site (NB-7 = NBH-G).

Nutrient sampling and analytical data generated from October 2005 through October 2015 were evaluated against the performance criteria in the quality assurance project plan and are summarized in detail in Appendix F.

Samples were collected monthly for nitrate-nitrite, ammonia, total nitrogen (Kjeldahl or persulfate digestion), total phosphorus (TP) and orthophosphate at all gauging stations with exceptions in November 2008 and November 2010. Synoptic samples were collected quarterly for ammonia and nitrate-nitrite, with synoptic sampling on Deer Creek scaled back in 2010. Nutrients samples were collected monthly at the gauging stations, with missing data representing <3% at the gauging stations over the course of the study. Synoptic site sampling frequencies varied over the course of the study. Episodes where synoptic samples were not collected represented 18% of all Deer Creek synoptic sites, 2 to 12% for various Flynn Creek synoptic sites, and 2 to 7% of Needle Branch synoptic sites. Samples not collected because stream segments were dry were primarily from tributary streams in July through September. Forty sites were dry in Needle Branch, 14 in Deer Creek, and 15 in Flynn Creek. All dry sites were tributary sites except NBU, the upper Needle Branch gauging station, which was noted as dry once in September 2007 and once in August 2015. The sites most frequently dry were UNB-C (20) and NB-3 (8) in Needle Branch, DC-8 (7) in Deer Creek, and FC-7 (12) in Flynn Creek. Sample collection was initiated at the UNB-C site in October 2007, and that site was dry from July through September in most water years. Sampling at all tributary sites was discontinued in September 2014.

Field duplicate precision passed the acceptance criteria for all parameters with measurable concentrations except four out of 33 field duplicates analyzed for total phosphorus that exceeded the 35% relative percent difference (RPD) criteria. Field precision could not be determined for ammonia because results were at or near quantitation limits or blank levels, and could not be determined for total phosphorus or TKN when the copper sulfate digestion reagent was used because of highly variable blank levels.

Analytical performance was assessed by conducting method blanks, independent calibration checks (ICV), continuing calibration checks (CCV), sample duplicate analyses, matrix spikes (MS), and matrix spike duplicates (MSD) with each analytical batch. When analyses required a digestion procedure digestion independent calibration checks (dICVs) and digestion continuing calibration checks (dCCVs) were taken through the entire analytical process. When sample results were at or near corresponding method blank levels or at the method quantitation limit precision was assessed using the MS/MSD relative percent difference.

Table 6 provides an overview of the results of these analyses. “Pass” indicates that all analyses met acceptance criteria or did not present interference problems. Method blank levels caused interferences with low level sample analyses for some nutrient parameters, influencing reliability of low level sample results. These data were flagged because concentrations measured in the samples were less than or equal to one times the method blank (B1) or less than or equal to two times the method blank (B2). Performance checks that failed to meet QA/QC acceptance criteria are shown in relation to the number of overall analyses performed. Precision includes both sample and MS/MSD duplicate RPDs.

Table 3.6. Nutrient Method Performance

Parameter	Method Blank	ICV	CCV	dICV	dCCV	Precision	Matrix Spike
Nitrate-nitrite	Pass	Pass	Pass	NA	NA	Pass	Pass
Ammonia	Blank flag	Pass	Pass	NA	NA	Pass	1/206
TKN	Blank flag	Pass	Pass	7/49	20/75	5/103	21/107
TNP	Pass	Pass	Pass	1/70	8/210	Pass	4/143
Orthophosphate	Pass	Pass	Pass	NA	NA	4/233	Pass
TKP	Blank flag	Pass	1/15	1/5	1/11	Pass	3/18
TPP	Pass	Pass	Pass	Pass	2/259	3/204	Pass

Overall, these data are high quality with very low instances of QA/QC performance failures, except when Kjeldahl digestion procedures were used. With the exception of one CCV for TKP, all ICVs and CCVs met 80 to 120% acceptance criteria. More than 97% of dICVs and dCCVs also met these criteria, exclusive of Kjeldahl digestion data. Duplicate measurements passed the <25% relative percent difference precision criterion more than 98% of the time, and MSs passed a 70 to 130% recovery criterion more than 98% of the time, exclusive of Kjeldahl digestion data. Results of nitrate-nitrite analyses are of the highest data quality, having passed all QA/QC performance criteria.

Ammonia analyses also passed all performance checks except one MS recovery that was outside the acceptance range. However, most ammonia concentrations measured in the samples were within three times the method blank levels and are flagged in the database as B1, B2, or B3, indicating a result was less than or equal to one, two, or three times the blank level, respectively. These measurements were discontinued in September 2014 because concentrations had been too low to statistically evaluate these data before and after harvest or between control and harvest streams.

Data for TKN were unreliable due to high method blank levels compared with low sample concentrations and moderately high failure rates of method QA/QC, which is why these analyses were discontinued and TN measurements using alkaline persulfate digestion (TNP) were initiated instead. Unfortunately, this will make it difficult to assess differences before and after harvest and between paired watersheds. TNP analyses passed >96% of QA/QC performance criteria for dICVs and dCCVs and >96% of matrix spike recoveries. Total nitrogen concentrations should be evaluated against nitrate-nitrite concentrations to determine whether there is a statistical difference in the results that indicates a sufficient organic nitrogen contribution that could be differentiated before and after harvest or between the control and harvest streams.

Orthophosphate analyses were also of high data quality. All QA/QC performance criteria were met except for four sample duplicates with RPDs >25%.

Analyses for total phosphorus using the Kjeldahl digestion procedure were also unreliable due to high method blank levels compared with low sample concentrations. The TKP method was used for 9 months of the 10-year study summarized herein. These analyses were discontinued, and total phosphorus measurements using acidic persulfate digestion (TPP) were initiated. TPP measurements passed all ICV and CCV performance criteria, >99% of dICV and dCCV criteria, and 98% of all precision measurement criteria.

3.6 Herbicide Study Data Quality

NCASI Special Report SR 13-01, prepared by Jeff Louch (NCASI 2013), summarized results of measurements of glyphosate, aminomethyl phosphoric acid (AMPA), imazapyr, sulfometuron methyl and metsulfuron methyl in Needle Branch streamwater following an aerial spray application. Appendix G summarizes the herbicide study data quality as discussed in NCASI (2013). Data gaps related to the operations of the automated samplers were noted in NCASI (2013). These sampler malfunctions affected the extent of analysis possible in the investigation, which is discussed herein.

3.6.1 Sample Collection Data Gaps

The investigation was set up to manually trigger automated samplers when a storm approached. There were multiple instances of sampler malfunction that led to no samples or a reduced number collected during a storm, leading to a loss of data for some sample periods at some locations. There was also a lower than expected concentration of glyphosate during the first storm at the upper site. In the second storm, the upper site had twice the concentration of the downstream site, which was the expected outcome during the first storm. We have no information to suggest those results are not valid, other than some of the other problems in automated sampler operation. One hypothesis is that given the dry antecedent conditions, there was very little runoff at the uppermost weir, although the available data appear to show a descending limb at the beginning of data collection.

Table 3.7 summarizes the final sample count per sampling site. Samples for determination of imazapyr, sulfometuron methyl, and metsulfuron methyl were preserved at pH 7 at the time of collection. Samples for determination of AMPA and glyphosate were not pH preserved but were frozen for long-term storage.

Table 3.7. Number of Samples Collected from Each Sampling Site as Part of Each Sampling Event

Sampling Dates				Unpreserved Samples			pH 7 Preserved Samples		
Start	End	DAT[a]	Event	NBL	NBU	NBH	NBL	NBU	NBH
08/22/10	08/23/10	0	Baseflow[b]	24	4[c]	24	24	24	1[d]
08/25/10		3	Baseflow	1	1	1	1	1	1
08/30/10	09/01/10	8-10	Storm	45	48	46	0[e]	48	48
09/10/10		19	Baseflow	1	1	1	1	1	1
09/14/10		23	Baseflow	1	1	1	1	1	1
09/15/10	09/21/10	24-30	Storm	53	54	54	54	54	54
09/24/10		33	Baseflow	1	1	1	1	1	1
10/01/10		40	Baseflow	1	1	1	1	1	1
10/08/10		47	Baseflow	1	1	1	1	1	1
10/08/10	10/10/10	47-49	Storm	0[f,g]	14[g]	14[g]	19	19	19
10/14/10		53	Baseflow	1	1	1	1	1	1
10/22/10		61	Baseflow	1	1	1	1	1	1
10/23/10	10/25/10	62-64	Storm	11[h]	23	24	23	23	24
11/05/10		75	Baseflow	1	1	1	1	1	1
11/18/10	11/19/10	88-89	Storm	11	15	15	15	14	15
11/20/10		90	Baseflow	1	1	1	1	1	1
12/03/10		103	Baseflow	1	1	1	1	1	1
12/10/10	12/12/10	110-112	Storm	27	6[i]	9[i]	36	25	30
				182	175	196	182	218	202

[a] DAT = days after treatment (application of herbicides)
[b] Teledyne ISCO samplers collected one sample per hour starting 3 hours prior to application of herbicides during baseflow conditions.
[c] The Teledyne ISCO sampler collected samples one through three and then malfunctioned; an additional grab sample was collected ≈24 hours after the application of herbicides.
[d] The Teledyne ISCO sampler malfunctioned; a single grab sample was collected ≈24 hours after the application of herbicides.
[e] The Teledyne ISCO sampler malfunctioned.
[f] The Teledyne ISCO sampler malfunctioned during the first portion of the storm event.
[g] The samples collected by Teledyne ISCO samplers during the second portion of the storm event were not retained.
[h] The Teledyne ISCO sampler malfunctioned after collecting 10 samples; an additional grab sample was collected at the end of the storm event.
[i] A reduced number of NBU and NBH samples were retained during the first portion of the storm event; none were retained from the second portion.

In multiple instances, sampler malfunction led to either no samples or a reduced number of samples being collected during a specific storm event (Table 3.7). In addition, some samples collected during later storm events were not retained. Specifically, only a subset of the samples for determination of AMPA and glyphosate (unbuffered samples) collected during the storm events from October 8 to October 10, 2010, and December 10 to December 12, 2010, were retained. This decision was informed by analytical results showing that AMPA and glyphosate were not detected in earlier storm events. This was also the basis for terminating the collection of samples for imazapyr, sulfometuron methyl, and metsulfuron methyl after the storm event from December 10 to December 12, 2010.

3.6.2 Sample Collection and Stage Data

Figure 3.2 shows stage (water height at the flume) data for NBL covering the period over which most samples were collected. Although a limited number of samples collected after October 27, 2010, were analyzed and results were reported in the appropriate appendices of NCASI 2013, these samples are not shown in Figure 3.2. Figure 3.2 shows when storm event and baseflow samples were collected for determination of herbicides. As noted in Section 3.6.1, samples were collected at all three sites at the same time; that is, each sample point shown in Figure 3.2 represents a sample collected at NBH, NBU, and NBL. NBL stage data clearly reflect the effects of each storm event. More importantly, the figure also shows that the sample collection regimen effectively sampled each storm event.

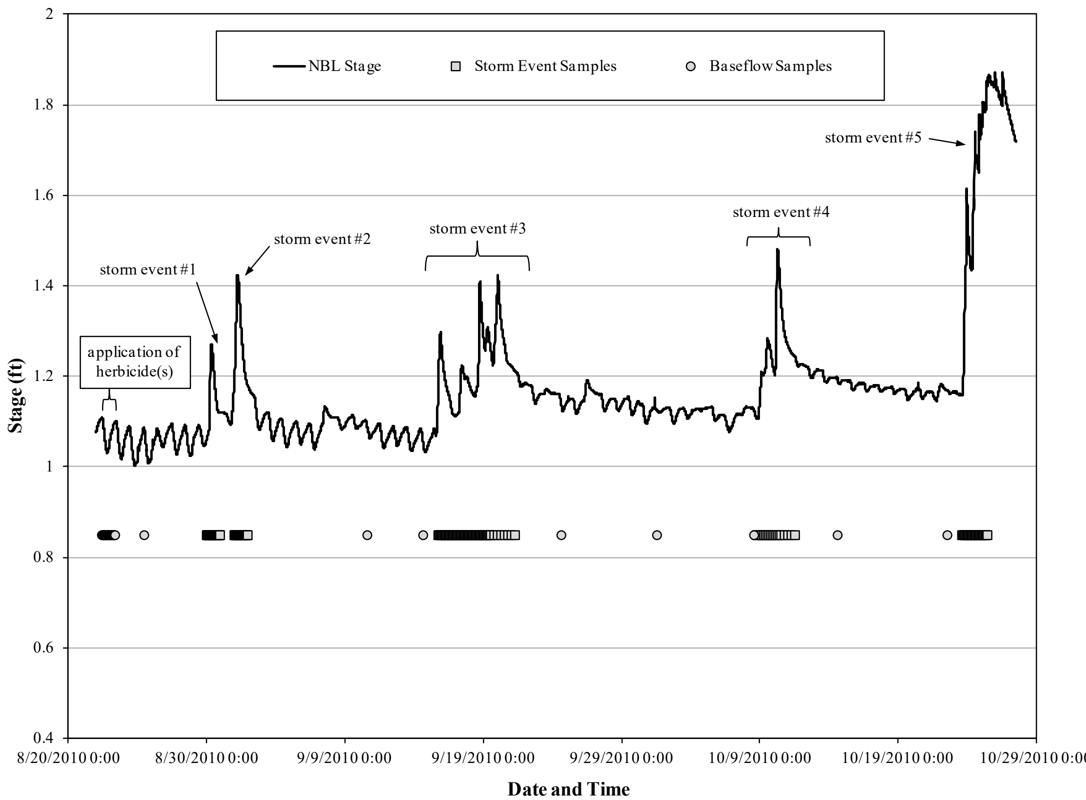

Figure 3.2. Stage Level at NBL from 8/22/2010 through 10/27/2010 with Identification of All Sampling Events

3.6.3 Herbicide Data Analyses

Herbicide analyses results indicated variable levels of background interference resulting in a high bias in analytical results for most herbicides (NCASI 2013). Regardless of this interference, glyphosate was the only parameter to show levels that could be differentiated from background. Results of glyphosate analyses conducted during the first two storm events are illustrated in Figure 3.3.

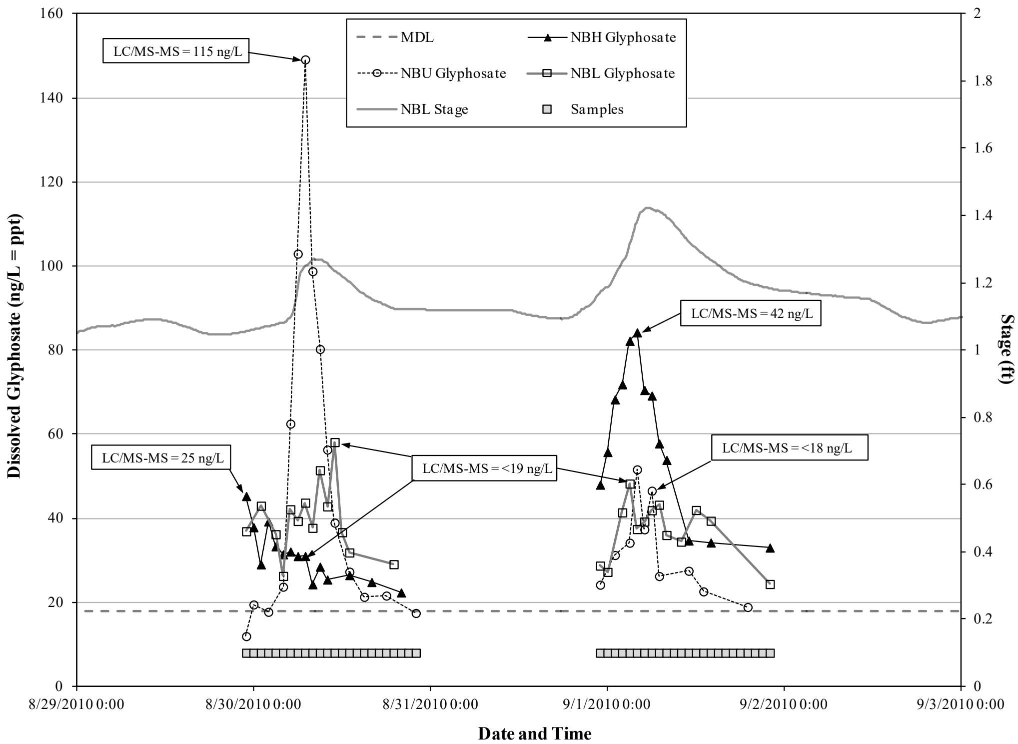

Figure 3.3. Dissolved Glyphosate at NBH, NBU, and NBL During First Two Storm Events After Application of Herbicides with Results from Liquid Chromatography Tandem Mass Spectrometry (LC/MS-MS) Confirmations (all concentrations plotted regardless of minimum detection limit (MDL)) (NCASI 2013)01)

In summary, the herbicide study results support these statements regarding dissolved glyphosate in streamwater collected during storm events:

- During the first two storm events after application (8 and 10 DAT), dissolved glyphosate manifested in streamwater as discrete pulses with a duration of 8 to 10 hours.
- No pulses in dissolved glyphosate were observed in later storm events.
- The maximum concentration observed during storm events decreased from NBH to NBU to NBL (i.e., decreased going downstream from the application site).
- The maximum concentration observed at each site decreased with each storm event.
- The dissolved glyphosate in streamwater collected at NBL during the first storm event (8 DAT) was <20 ng/L[1] (i.e., no pulse of dissolved glyphosate was observed at NBL during any storm event).
- The dissolved glyphosate was <20 ng/L at NBU by the second storm event (10 DAT).
- The dissolved glyphosate was <20 ng/L at NBH by the third storm event (24 DAT).

[1] Based on results obtained from LC/MS-MS confirmation analysis.

- The highest dissolved glyphosate concentration found in any sample was 115 ng/L at NBU during the first storm (8 DAT); this concentration persisted for no more than 2-3 hours.

The last of these statements should be qualified by noting that no pulse in dissolved glyphosate was observed at NBH during the first storm event. Based on the totality of these results, a pulse at NBH was expected, and it would also be expected that the maximum concentration in this pulse would be higher than that seen at NBU during the same storm event. Thus, the 115 ng/L observed at NBU during the first storm event following application of herbicide may not have been as high as would have been found at NBH during the same storm event.

The measured dissolved AMPA was <12 ng/L in all baseflow and storm event samples, and dissolved AMPA in streamwater collected during storm events was generally at concentrations equivalent to those found in baseflow. In no case was a clear pulse of dissolved AMPA observed during a storm event. Taken together, these factors suggest that all measurements reflect variability in the background interferent known to be present in all samples rather than the actual presence of AMPA. The measured concentrations certainly carry high bias due to this background, and all were less than the 15 ng/L instrumental calibration (ICAL) lower calibration level (LCL) for AMPA. Thus, the most defensible conclusion that can be drawn from these results is that the dissolved AMPA was <15 ng/L in all streamwater samples collected during storm events.

4.0 SUMMARY

Most water quality data collected in the main study were complete and of good to high quality (e.g., sediment, nutrients, and dissolved oxygen). However, problems related to flow may create challenges for analysis of those data in conjunction with other parameters (e.g., estimation of load vs. concentration). Data gap issues associated with the herbicide study are unfortunate, but while they limit the analyses to some degree, the overall data set is unique and robust. The gap in flow data during the 2010-2011 winter is also unfortunate and directly affects analyses of flow, suspended sediment, turbidity, and nutrient loads. This created a gap in the continuous record, and although course approximations through rating course reconstruction may be possible for flow data, the lack of samples for turbidity and suspended sediment is problematic. This gap may also limit statistical approaches available to researchers and, at the least, reduce winter sample sizes after the first harvest. The weir at the control watershed is an issue. Reconstruction of the flow regime through various methods is necessary, and those approximations may or may not be adequate for various analyses. The temperature equipment malfunctions in 2007 limit not only spatial assessment for that year but also long-term timelines. There were still four instruments for before and after harvest, but they were only at the weir sites. Overall, planned publications should be able to be completed with data sets that can be developed with the reconstructed flow regimes. Clear descriptions of those data adjustments are characterized in the Menk and Stednick report (Appendix B1). Documentation of data gaps, quality assurance and quality control in this report will aid researchers in understanding the details of these datasets, including their potential utility and/or limitations to address specific research questions.

5.0 RECOMMENDATIONS

Menk and Stednick outlined a series of new recommendations to improve streamflow measurement and water yield quantification generally applicable to all stations. Station-specific recommendations follow in Sections 5.1-5.5.

- A common and readily accessible database needs to be built and maintained. All data need to be uploaded shortly after collection. A common naming/labeling system needs to be implemented. Similarly, field notes, anecdotal observations, and pictures should be included.
- Standard nonrecording rain gauges should be placed in and around the study watersheds for additional precipitation data collection and to validate tipping bucket rain gauges. Alter shields are less important than additional rain gauges.
- Stream gauging stations all should have “outside” staff gauges (rather than depth to water minus benchmark elevation calculations), including NBH and NBU. The weirs and the flumes are not self-maintaining with respect to organic debris and sediment accumulation in the weir ponds or flume itself. Routine maintenance will include removing said debris. However, stage measurements should include “before and after” readings to allow better estimation of stage before debris accumulation. Other than prevention of backwaters impeding the downstream flume discharge, downstream channel maintenance efforts are generally not needed.
- Gauging stations at NBL, DCG, and FCG (all originally built by the US Geological Survey) have inside stage gauges located in their stilling wells. These stage readings should be included in the routine maintenance of gauging stations. This confirms the stage reading and a responsive hydraulic connection between the stilling well and inlet pipes (stream level). See a proposed discharge measurement form in Appendix F (p. 1.23) in Appendix B1.
- More site visits should be made to gauging stations and there should be increased recording of stage during site visits. Stage values are rarely corrected or adjusted, but stage shifts are recognized at all streamflow gauging stations. Stage notes can be collected on the proposed discharge form in Appendix F (p. 1.23) in Appendix B1.
- All weirs and flumes are subject to leakage. It is advised that a small amount of fluorescein dye be injected into the upstream channel, especially during low flows, to identify structure leakage. Maintenance can include caulking, mortar, or waterproof epoxy.
- Increased streamflow measurements should be made to build better rating curves for all stations. The rating curve (stage-discharge relationship) should not be considered constant. All stations are subject to channel shape changes that will affect the rating curve. The lower portion of the rating curve is subject to change. Offsets are rarely addressed in the streamflow reduction. Units are often problematic, whereby streamflow may be measured as meters per second (m/s) and then incorrectly converted to feet per second (ft/s). See the proposed discharge measurement form in Appendix F (p. 1.23) in Appendix B1. We advise that each discharge measurement be plotted to assess rating curve functionality and consistency. A point to the left of the curve will show backwater conditions. Conversely, a point to the right of the curve may show a steeper energy slope, as on a rising limb. Each gauging station has a zero-flow stage that needs to be included in the rating curve.

5.1 Flynn Creek Recommendations

A decision on Flynn Creek needs to be made as to its added value for streamflow monitoring. A second pressure transducer was placed in the Flynn Creek weir pond in 2007 to record stage values. Using two stage values, near the weir and at the head of the weir pond, would allow calculation of a water slope to estimate discharge as a step-backwater. These data, or the second pressure transducer, have apparently been lost. Better discharge estimates would improve the rating curve. The current rating curve is very poor. It is difficult to re-create past streamflow values, and a predictive equation would have to be developed, probably from Deer Creek, as precipitation data were inconsistent between stations. Storm event precipitation records are also frequently missing.

The gauging station at FCG has an inside stage gauge located in the stilling well. These stage readings should be included in the routine maintenance of the gauging station.

5.2 Deer Creek Recommendations

The gauging station at DCG (originally built by the US Geological Survey) has an inside stage gauge located in the stilling well. These stage readings should be included in routine maintenance of the gauging station.

5.3 Lower Needle Branch Recommendations

The gauging station at NBL (originally built by the US Geological Survey) has an inside stage gauge located in the stilling well. These stage readings should be included in the routine maintenance of the gauging station.

5.4 Upper Needle Branch Recommendations

Stream gauging stations all should have “outside” staff gauges (rather than depth to water minus benchmark elevation calculations), including NBU.

5.5 Needle Branch H-Flume Recommendations

Stream gauging stations all should have “outside” staff gauges (rather than depth to water minus benchmark elevation calculations), including NBH.

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APPENDIX A
ALSEA STUDY MAPS AND SITE LOCATIONS

Synopsis prepared by Terry Bousquet, NCASI
Figures provided by Jeff Light and David Leer, Oregon State University

Nutrient and Temperature Logger Gauging and Synoptic Sites

Figures A1, A2, and A3 show the locations of gauging stations and synoptic sampling sites for nutrient sampling and temperature logger deployment at Needle Branch, Flynn Creek, and Deer Creek, respectively. In 2008, an H-flume and gauge were added in Needle Branch at the NB-7 site, which is identified as NBH for flow and discharge data.

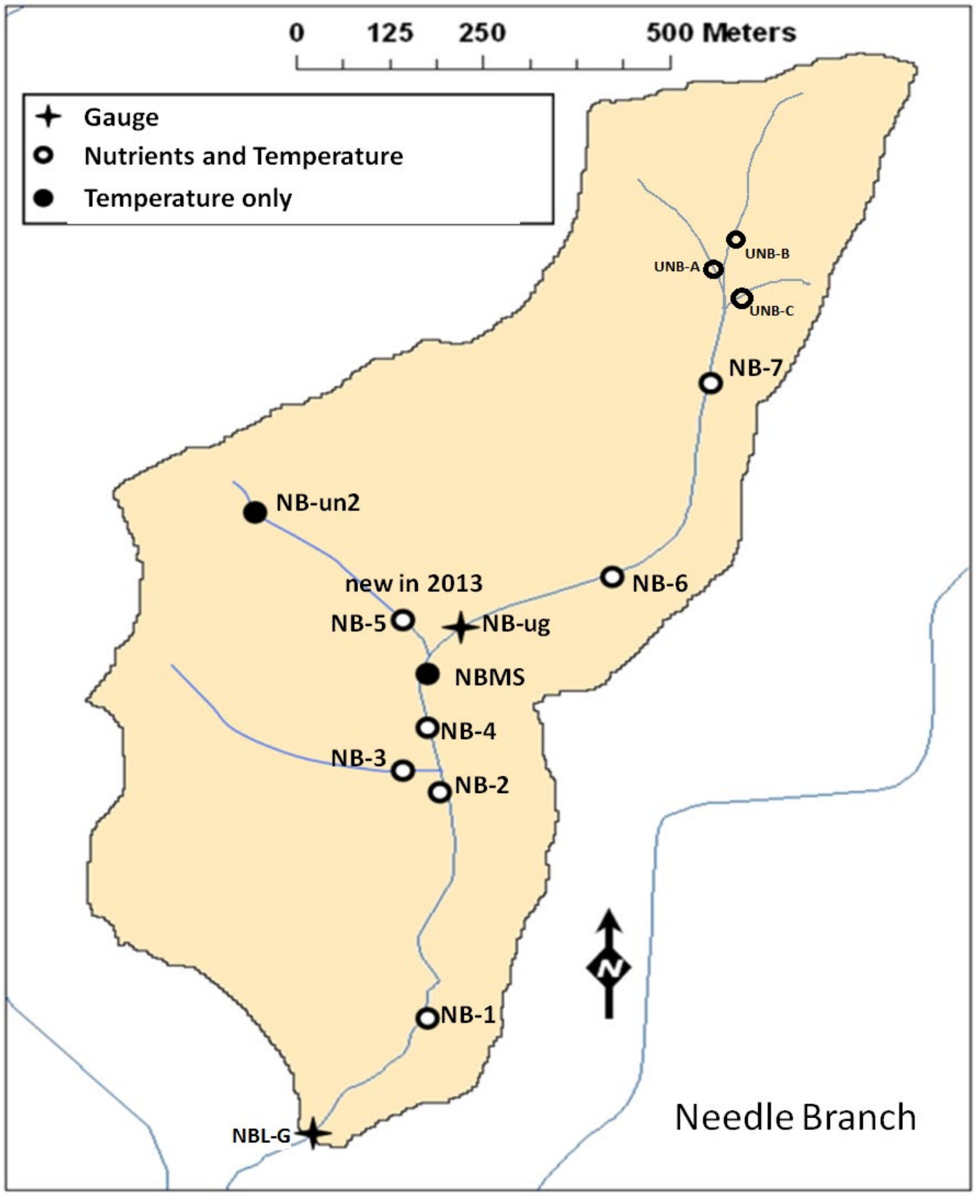

Figure A1. Temperature and Nutrients Site Locations for Needle Branch

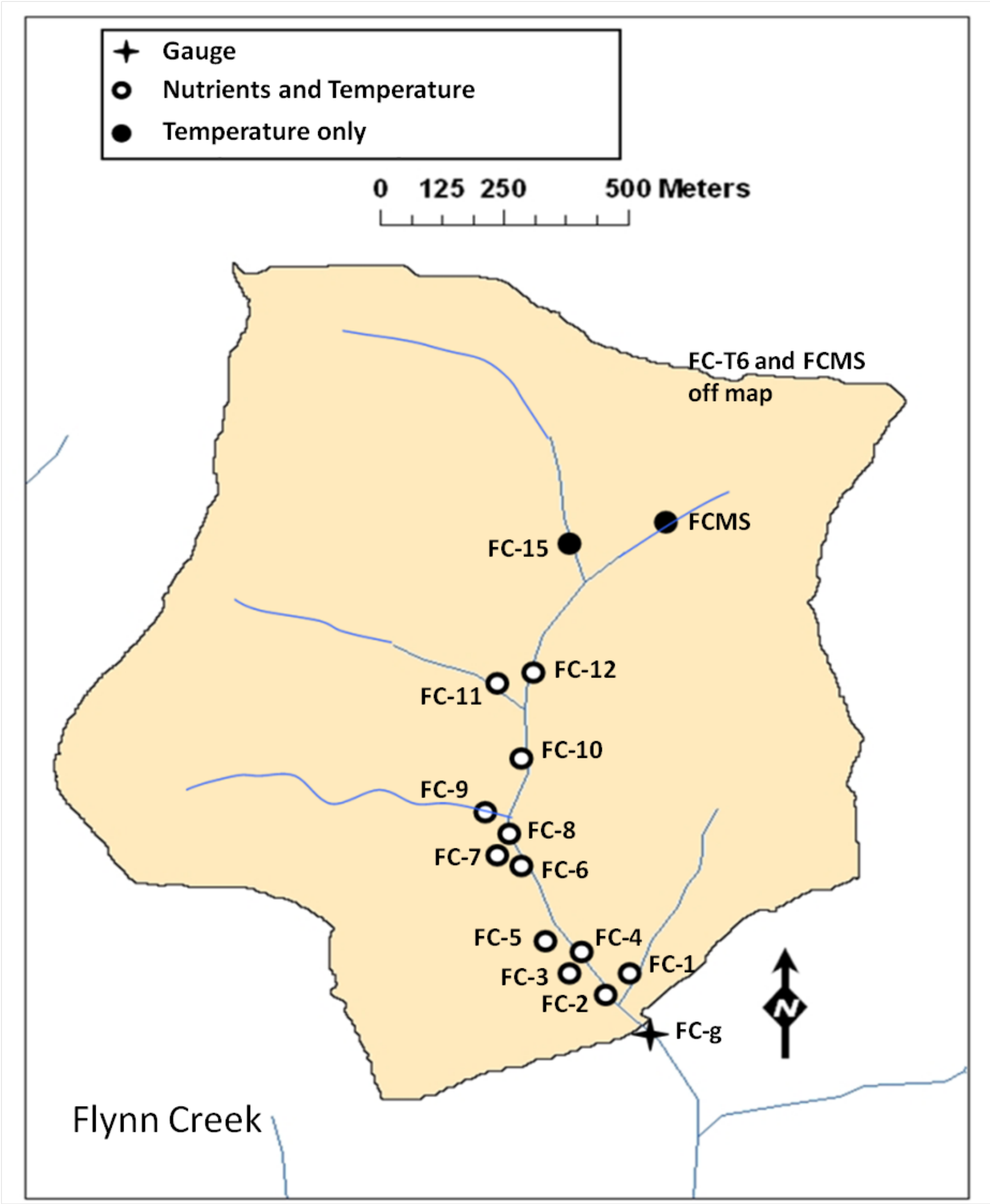

Figure A2. Temperature and Nutrients Site Locations for Flynn Creek

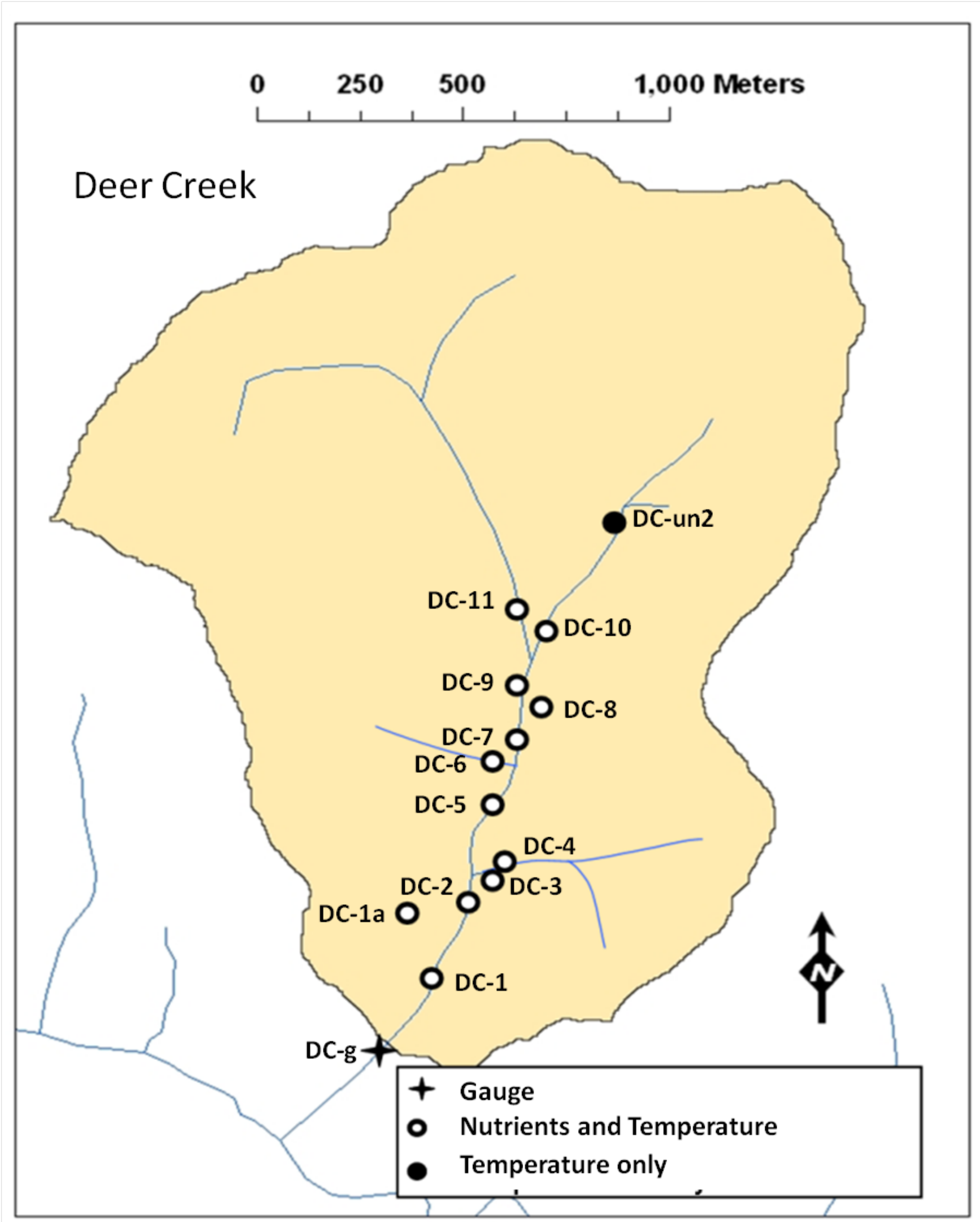

Figure A3. Temperature and Nutrients Site Locations for Deer Creek

Table A1 lists the nutrient sampling and thermistor site locations for each watershed, identifies the stream segment, and describes the site location type and purpose. Temperature measurements in Deer Creek were reduced to the gauging station beginning in 2008, with one additional site measured in 2008 and 2011.

Table A1. Nutrient Sampling and Thermistor Site Locations

Watershed	Site Location Identification	Description	Segment
Needle Branch	NBL-G	Weir/gauge temperature/nutrients	Main stem
	NBU-G	Weir/gauge temperature/nutrients	Main stem
	NB-1	Synoptic temperature/nutrients	Main stem
	NB-2	Synoptic temperature/nutrients	Main stem
	NB-3	Synoptic temperature/nutrients	Tributary
	NB-4	Synoptic temperature/nutrients	Main stem
	NB-5	Synoptic temperature/nutrients	Tributary
	NB-6	Synoptic temperature/nutrients	Main stem
	NB-7, NB7-G, NBH	Weir/gauge temperature/nutrients	Main stem
	UNB-A	Synoptic nutrients	Headwater Tributary
	UNB-B	Synoptic nutrients	Headwater Tributary
	UNB-C	Synoptic nutrients	Headwater Tributary
	NB-un1	Temperature	Main stem
	NB-un2	Temperature	Tributary
	New 2013	Temperature	Tributary
Flynn Creek	FC-G	Weir/gauge temperature/nutrients	Main stem
	FC-1	Synoptic temperature/nutrients	Tributary
	FC-2	Synoptic temperature/nutrients	Main stem
	FC-3	Synoptic nutrients	Tributary
	FC-4	Synoptic nutrients	Main stem
	FC-5	Synoptic nutrients	Tributary
	FC-6	Synoptic temperature/nutrients	Main stem
	FC-7	Synoptic nutrients	Tributary
	FC-8	Synoptic nutrients	Main stem
	FC-9	Synoptic temperature/nutrients	Tributary
	FC-10	Synoptic temperature/nutrients	Main stem
	FC-11	Synoptic temperature/nutrients	Tributary
	FC-12	Synoptic temperature/nutrients	Main stem
	FC15 (trib5)	Synoptic temperature	Tributary
	FCMS	Synoptic temperature	Main stem above FC15
	FCMS	Synoptic temperature	Main stem above FCT6
	FCT6	Synoptic temperature	Tributary

Watershed	Site Location Identification	Description	Segment
Deer Creek	DC-G	Weir/gauge temperature/nutrients	Main stem
	DC-1	Synoptic nutrients	Main stem
	DC-1A	Synoptic nutrients	Tributary
	DC-2	Synoptic nutrients	Main stem
	DC-3	Synoptic nutrients	Tributary
	DC-4	Synoptic nutrients	Tributary
	DC-5	Synoptic nutrients	Main stem
	DC-6	Synoptic nutrients	Tributary
	DC-7	Synoptic nutrients	Main stem
	DC-8	Synoptic nutrients	Tributary
	DC-9	Synoptic nutrients	Main stem
	DC-10	Synoptic nutrients	Tributary
	DC-11	Synoptic nutrients	Main stem
	DC-un2	Temperature	Tributary

Needle Branch Harvest Areas

The photograph in Figure A4 shows the 2009 harvest, terminating at the Upper Needle Branch gauging station. The 2014 harvest is represented by the forested area between Upper Needle Branch (NBU) and Lower Needle Branch (NBL) sites.

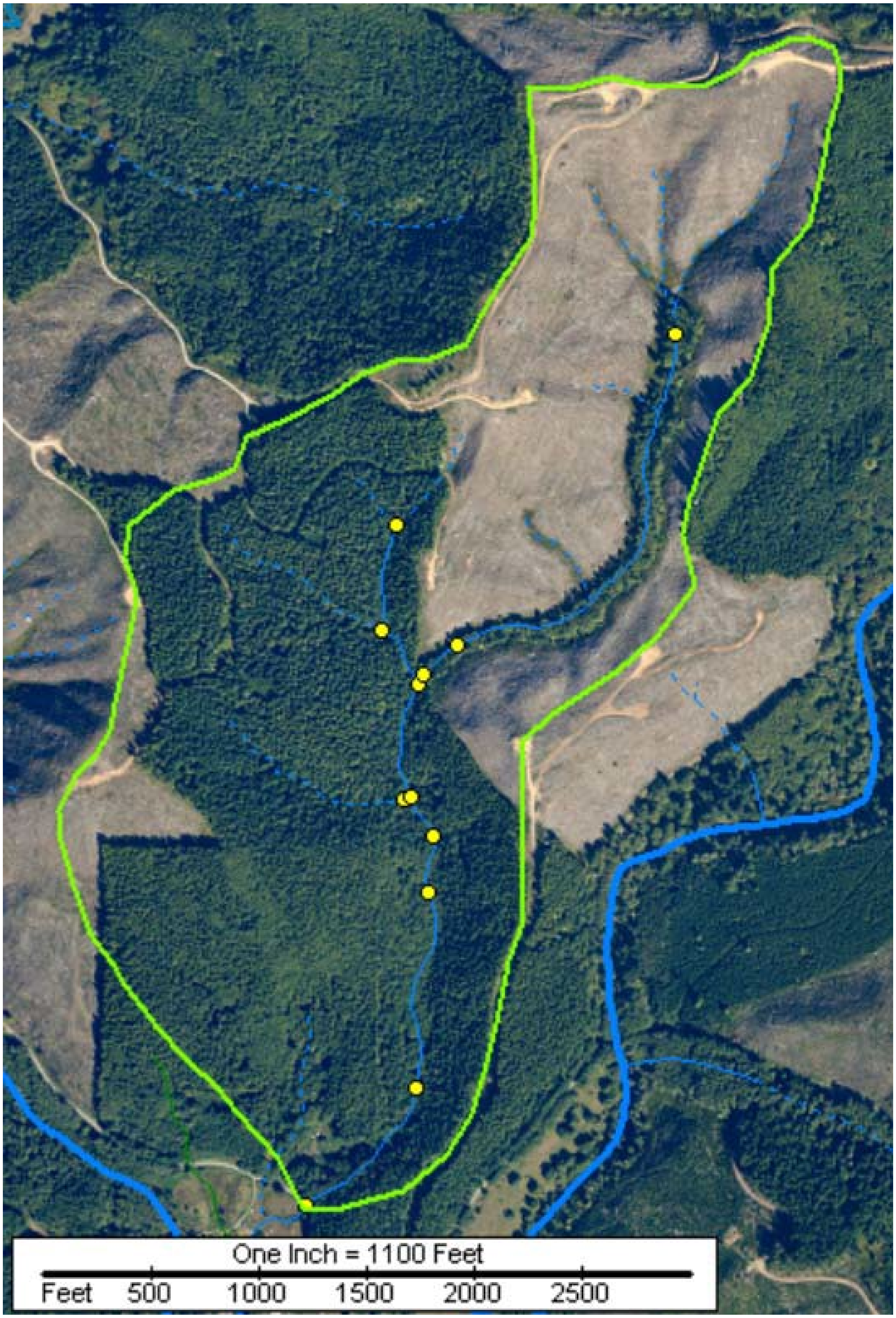

Figure A4. Needle Branch Showing 2009 Harvest

APPENDIX B

ELECTRONIC DATA LOGGER STAGE, TURBIDITY, TEMPERATURE, AND CONDUCTIVITY MEASUREMENT AND DISCHARGE DETERMINATION DATA QUALITY ASSESSMENT

Synopsis Prepared by Robert Danehy and Terry Bousquet, NCASI
Field Protocols, Data Analysis, and Stream Discharge Appendix B1 Prepared by Matthew Menk and John Stednick, Colorado State University, and Stream Discharge Appendix B2 Prepared by Catalina Segura, Oregon State University
Field Sampling, Field Work, and Data Collection Conducted by Cody Hale and David Leer, Oregon State University
Database Management by Amy Simmons, Oregon State University

Introduction

This appendix provides an overview of stage and discharge data quality derived from reports prepared by Matthew Menk and John Stednick (Colorado State University) describing field protocols and discharge determinations for each gauging station. The Menk-Stednick reports are included as Appendix B1 to this data quality report. Additionally, another addendum of discharge records (2006-2015) prepared by Catalina Segura (Oregon State University) is also provided (Appendix B2), but details presented here (Appendix B) focus on the Menk-Stednick report, which encompasses the years 1992-2015. Stage (CS420-L Druck pressure transducer), temperature (CS547A-L temperature and conductivity sensor), turbidity (OBS-3 turbidity meter), and conductivity (CS547A-L temperature and conductivity sensor) were measured in situ every 10 minutes at the gauging stations on Needle Branch, Flynn Creek, and Deer Creek using electronic data loggers. Pressure transducers determined stage, and probes measured turbidity, temperature, and conductivity. Turbidity thresholds in conjunction with stage triggered the collection of suspended sediment samples via an automated sampler (Teledyne ISCO 3700C). Data quality assessments of suspended sediment analyses and laboratory measurements of turbidity are discussed in Appendix C, and temperature data quality is discussed in Appendix D or the Data Quality Report for the Alsea Watershed Study Revisited Water Quality Measurements.

The gauging stations on Flynn Creek (FCG), Deer Creek (DCG), and the lower gauging station on Needle Branch (NBL) are the same locations used in the original Alsea Watershed Study. An upper Needle Branch (NBU) gauge was added in October 2006, an H-flume was installed, and an additional gauging station was deployed farther upstream on Needle Branch at the NB-7 synoptic site in December 2008. This site was identified as Needle Branch H-flume (NBH), indicating the H-flume. This appendix describes the types and locations of weirs, discusses measurement equipment and stage data collection, characterizes stage data quality and discharge determinations, summarizes the overall quality of discharge data, provides recommendations for discharge data improvement, and presents an assessment of corresponding water quality measurement quality assurance/quality control for turbidity, temperature, and conductivity.

Types and Locations of Weirs

A weir is an overflow structure built in an open channel to measure flow rate. Weirs in the Alsea watershed were from the US Geological Survey (USGS) era (1958-1973) and are broad-crested compound weirs as shown in Figure B1. Stage or head measurements, the measured depth of water above the weir notch, are used to determine flow from a rating table or rating curve (see section titled "Stage-Discharge Relationships"). There are three broad-crested compound weirs located at the base of each watershed within Alsea: DCG, FCG, and NBL. All of these weirs were installed by the USGS in 1958 (Appendix B1). The Flynn Creek weir is shown in Figure B1.

Figure B1. Broad-Crested Compound Weir at Flynn Creek and Outside Staff Gauge in Pool on River Right

Flynn Creek Weir Issues

The weir at Flynn Creek captured sediment upstream. In addition, a downed tree caused a backup downstream of the weir (Figure B2). Historically, US Forest Service accounts described a need to periodically remove fill on the upstream side of the weir. That condition can be seen in the center panel of Figure B2. Sandbags were placed on either side of the approach reach to guide the flow through the weir, but note the surface ripples even at relatively low flow conditions. Also, in the right panel, note the high alluvial bank on the right. The weir is a sediment trap. In the left panel, there are the remains of a fallen tree. A larger stem has been removed. During high flows, a pool forms, backing up flow and causing deposition on the downstream side and backwatering above the weir crest. The vegetated area in the near view of the left panel is in deposited alluvium.

These depositions are both long term (permanent) as well as short term and change after storm events. This has led to inconsistent flow measurements and the need for multiple rating curves (see section titled "Flynn Creek Stage-Discharge Relationship").

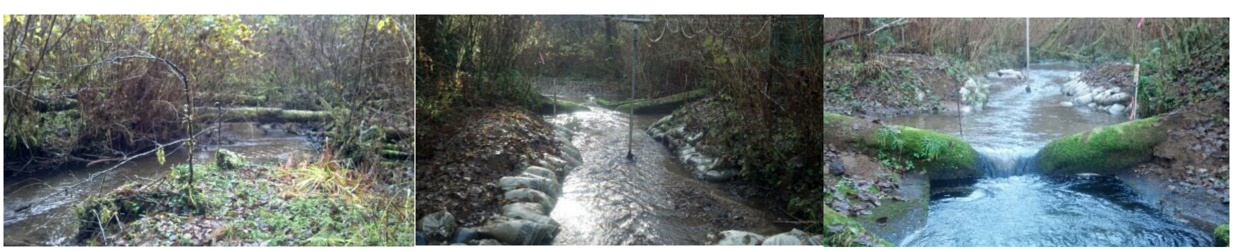

Figure B2. Flynn Creek Weir Downstream (left panel), Upstream Down to Weir (center panel), and from Below Weir Upstream (right panel)

NBU Weir

There is an 18-inch, 45-degree trapezoidal flume manufactured by Plasti-Fab installed at NBU as shown in Figure B3. This trapezoidal flume has application advantages over other flumes and weirs because the bottom is level and does not require a free-fall discharge to operate correctly (Plasti-Fab, 2015).

Figure B3. Trapezoidal Flume at NBU Gauging Station

NBH Weir

There is a 3-foot H-flume manufactured by Tracom installed upstream of the Upper Needle Branch site, which is identified as NBH (Figure B4). H-type flumes provide excellent accuracy for a wide range of flows in open channels where free-falling discharge conditions occur. H-flumes differ from other flumes as they more closely resemble V-notch weirs than flumes due to their exit geometry (Tracom, 2015).

Figure B4. H-flume at NBH Gauging Station

Data Collection Equipment and Procedures

As illustrated in Figure B5, data were collected from Leupold & Stevens, Model A-35 stage recorders (Leupold & Stevens Company, Beaverton, OR) and from instrumentation associated with the turbidity threshold sampling (TTS) protocol developed by the US Department of Agriculture (USDA), US Forest Service's Redwood Sciences Laboratory (Eads and Lewis 2003). The TTS equipment included a Campbell Scientific CR10x data logger (Campbell Scientific, Inc., Logan, UT), an OBS-3 turbidity probe (D&A Instrument Co., Port Townsend, WA), a CS420-L Druck pressure transducer (Druck Inc., New Fairfield, CT), a CS547A probe that measures temperature and conductivity (Campbell Scientific, Inc. Logan, UT), and a Teledyne ISCO 3700 automated sampler (Teledyne ISCO, Inc., Lincoln, NE). Total threshold sampling involves using turbidity thresholds in conjunction with stage data to trigger the collection of suspended sediment samples via the automated sampler. The sampler collects fixed volumes of water into 1-liter bottles at specified time intervals. Recorded data are downloaded to a laptop computer as described in field protocols developed by Cody Hale (2007) and included in Appendix B1. Turbidity and total suspended solids results determined from the TTS sample collection are discussed in Appendix C.

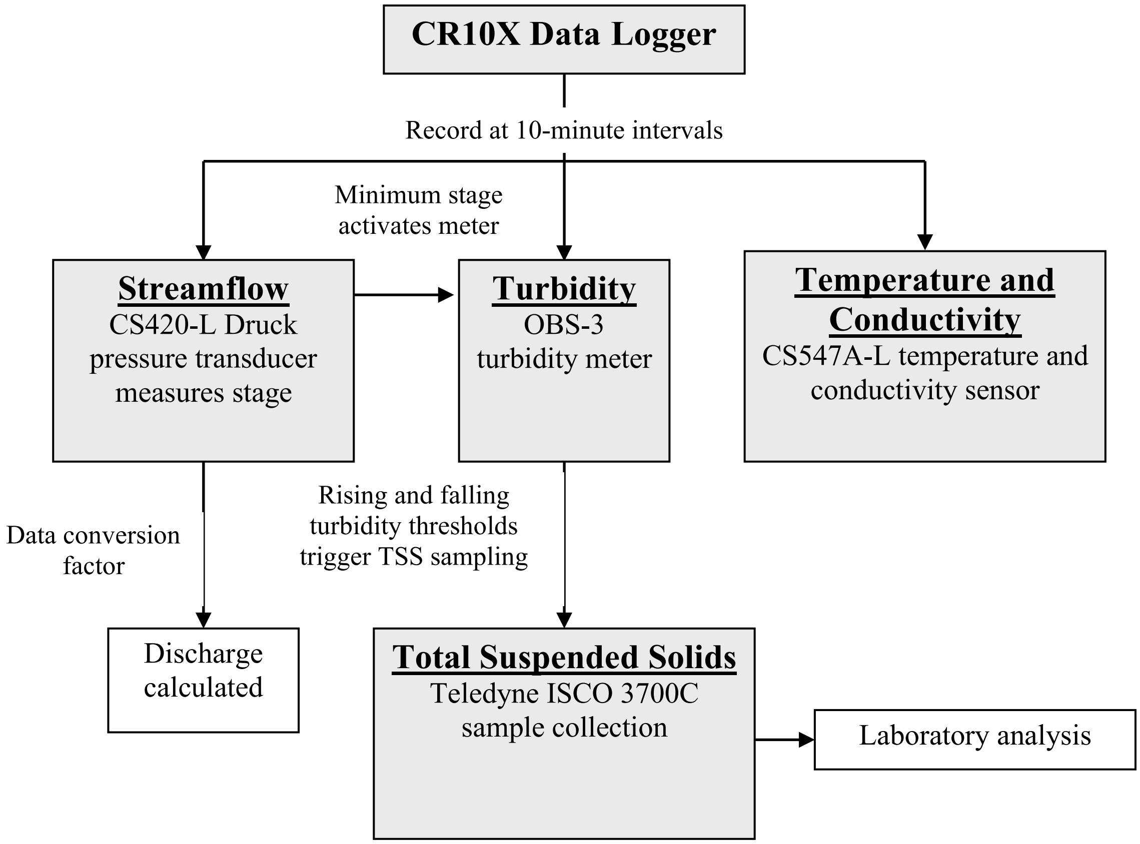

Figure B5. Data Logger Configuration and Monitoring Parameters

Stage data were collected every 10 minutes by a pressure transducer located in the weir stilling pond. These data were recorded on a data logger and physically downloaded at various intervals, and all files were shared at the water year end. There were very few stage corrections noted in field notes resulting from frequent debris removal and/or sediment removal from the stilling pond. The resultant higher stage measurement thus overestimates streamflow.

Rain Gauges

Appendix B1 provides a detailed discussion of rain gauge equipment and field protocols. Currently, all rain gauges used in theAlsea Watershed Study Revisited are Texas Electronics, Inc., TR-525M rainfall sensors. The TR-525M rainfall sensor is a remote, tipping-bucket-style rain gauge that measures rain intensity. This rain gauge has a resolution of 0.1 mm, an accuracy of 1% up to 2 in/hr (50 mm/hr) and can operate in temperatures from 32 to 125°F (0 to 50°C) (Texas Electronics 2014).

Sources of Errors in Rain Gauge Data Collection

Menk and Stednick note that there are several sources of errors to consider when determining rainfall characteristics: timing error, instrumental error, and sampling error. Timing errors occur among rain gauges and need to be corrected. For example, one gauge may record a 24-hour event on September 15, where a different rain gauge records the same event over a 24-hour period that covers September 14 and September 15. Instrumental error is related to the accuracy with which a rain gauge will catch the “true” rainfall amount at a point (Ffolliott, 1990). The most common instrumental error that occurs is wind-induced error. Because most rain gauges are elevated above ground, wind eddies that form around their openings reduce the amount of rain captured. This problem is known as wind-induced gauge undercatch and is considered the most common and largest source of rainfall-measurement error. Wind effect can be minimized by placing wind-shields around the gauges. Rain gauge openings often become clogged with organic matter and other debris. This can be minimized with regular site visits and maintenance of a screen covering the precipitation bucket drain hole (not the bucket orifice). Sampling error is a measure of how well rain gauges in a network represent rainfall characteristics of an entire watershed area. Sampling error can be minimized by increasing the number of rain gauges in and around a study area.

Data Processing and Missing Rain Gauge Data

Data processing should begin immediately after data from a rain gauge have been downloaded and should be completed as soon as possible to ensure that any malfunctions in instrumentation can be addressed in a timely manner.

Missing records in rainfall measurements is not an uncommon problem. This is due to gauge mechanical and electrical failures and is also caused by erroneous recording and publishing of rainfall measurements (University of Louisiana at Lafayette 2013). Missing data can be a problem for calculating water budgets, determining maximum rainfall intensities, and estimating area-average rainfall intensities. Several methods have been developed to estimate annual missing records at a certain station from concurrent measurements at nearby stations. These are discussed in more detail in the field protocols in Appendix B1.

Staff Gauges and Velocity-Area Determinations

Water-level readings were taken directly from staff gauges to validate TTS stage data. All main stream gauges have an inside staff (in the stilling well) and a reference (benchmark) to an outside staff reference. All these stations should have an outside staff installed to measure the same stage as the inside well. An example staff gauge is shown in Figure B6.

Figure B6. This Staff Gauge Reads a Stage Value of 2.92 Feet (Parker 2004)

All stream gauging stations have an outside staff gauge or means to measure the outside stage (i.e., distance to water surface subtracted from a benchmark). It is recommended that a permanent “outside” staff gauge be installed at FCG, DCG, and NBL. Outside staff gauges are already installed at NBU and NBH. There is an inside staff gauge (in the stilling well) for the main stations (FCG, DCG, and NBL) that should be read and recorded. This is a method to determine hydraulic connectivity between the stilling well and the stream water level. Outside staffs should be located in still waters and kept free of stream debris.

Sources of Errors in Data Collection

Sampling errors generally are not considered in measurements of discharge. However, errors in a rating curve should be considered (Ffolliott 1990). Errors in a rating curve can include, but are not limited to, errors in taking measurements that are required for developing a rating curve (i.e., velocity-area method), the statistical variability in the curve itself, and instrument-related errors (especially when a continuous water-level recorder is employed to determine the stage). Regular site visits and proper site maintenance, therefore, are very important. In addition, to confirm electronic stage data using staff gauges, a velocity-area-method had been used to validate stream flow data as described in field protocols (Appendix B1).

Validation of Stage Data

As described in Appendix B1, field personnel visually assessed the weirs and TTS booms for obvious interferences such as debris caught in the weir or on the instrumentation, sediment covering the stilling well intake, and/or American beaver (*Castor canadensis*) activity causing backwater effect in the vicinity of a gauge. Obvious problems were mitigated, and changes in stage and/or turbidity were noted in field notebooks. Stage measured at reference gauges were also recorded in a field notebook as follows:

1. TTS (from numeric window)
2. Reference stage (*verifies accuracy of instrumentation*): measure the outside reference “tape-down” with the staff plate located in each gauging house. Tape-down is located as follows:
    a. Flynn Creek—on the upstream side of the weir, right of the notch, top of bolt; subtract measured value from 3.27 to get reference stage in feet
    b. Needle Branch—on the left bank, weir approach wall, top of lowest bolt; subtract measured value from 2.89 to get reference stage in feet
    c. Deer Creek—on the upstream side of the weir, right of the notch, top of bolt; subtract measured value from 2.78 to get reference stage in feet

If TTS samples were collected, the data associated with each sampling event were retrieved from the data logger. Procedures for downloading continuous data records were described by Hale (2007) and Mend and Stednick (Appendix B1). The downloaded stage and turbidity data were plotted to determine any obvious problems that may need to be addressed in the field by plotting the raw data as described in Eads and Lewis (2003).

Discharge for each control structure should be plotted vs. time to observe any obvious data issues. In general, the larger the contributing area, the larger the discharge should be. To ensure data quality, two graphical comparisons should be made.

For the watersheds in the Alsea Watershed Study Revisited, the first graphical comparison made should include DCG, FCG, and NBL (Appendix B1). The highest discharge should be from DCG, followed by FCG, and NBL should have the lowest discharge. The second graphical comparison made should include NBL, NBU, and NBH. The highest discharge should be for NBL, followed by NBU, and NBH should have the lowest discharge.

Stage-Discharge Relationships

Stream-discharge relationships summarized in this appendix were developed by Menk and Stednick as discussed in Appendix B1. Stream discharge is one of the most difficult variables to measure continuously. The derivation of an empirical relationship between stage (water level) and discharge is fundamental to producing streamflow data. A true stage-discharge curve will hold its shape as the number of discharge measurements increases and will accurately predict streamflow in extrapolated areas, such as those areas that are outside the previously measured range. A stage-discharge curve is developed from a series of stage and streamflow measurements. These measurements are assumed to have homogeneous variance and are independent, neither of which is true. The curve is often fit statistically based on the correlation of determination, when in fact it should be better recognized as a hydraulics-derived function of the channel cross section. Care should be taken to identify the zero-flow point for each stream gauging station. Although Alsea includes artificial control sections, previous efforts by the USGS continued to identify stage shifts and needed offsets for NBL, DCG, and FCG gauging stations. Similarly, the flumes at NBU and NBH suggest a variable stage-discharge relationship due to debris and sediment accumulation in the flumes or poor hydraulic conductivity between the stilling well and water elevation in the flume.

Flynn Creek Stage-Discharge Relationship

A second pressure transducer was placed in the Flynn Creek weir pond in 2007 to record stage values. Using two stage values, near the weir and at the head of the weir pond, would allow calculation of a water slope to estimate discharge as a step-backwater. These second pressure transducer data have apparently been lost. Better discharge estimates would improve the rating curve. The current rating curve is very poor.

Menk and Stednick developed a relationship equation from Deer Creek to predict daily Flynn Creek stream flow values because past streamflow values could not be re-created, precipitation data were inconsistent between stations, and storm event precipitation records were frequently missing. Discharge at 10-minute intervals was not determined by Menk and Stednick because the entire FCG period of record was predicted. All streamflow data at FCG were predicted using DCG mean daily streamflow values (Equation B1). Flynn Creek mean daily discharge (Q) in cubic feet per second (cfs); minimum, maximum, and mean monthly discharge values; and annual water yield in inches and mean annual discharge for each water year from 2009 to 2015 are presented in the Menk and Stednick report (Appendix B1).

Equation B1: DCG vs. FCG Relationship

$$FCG\ Q[cfs] = 0.67(DCG\ Q[cfs])$$

$$R^2 = 0.98$$

Although the Alsea Watershed Revisited Study data were calculated using the DCG vs. FCG relationship equation, a rating curve was prepared to determine FCG discharge for future work (Figure B7).

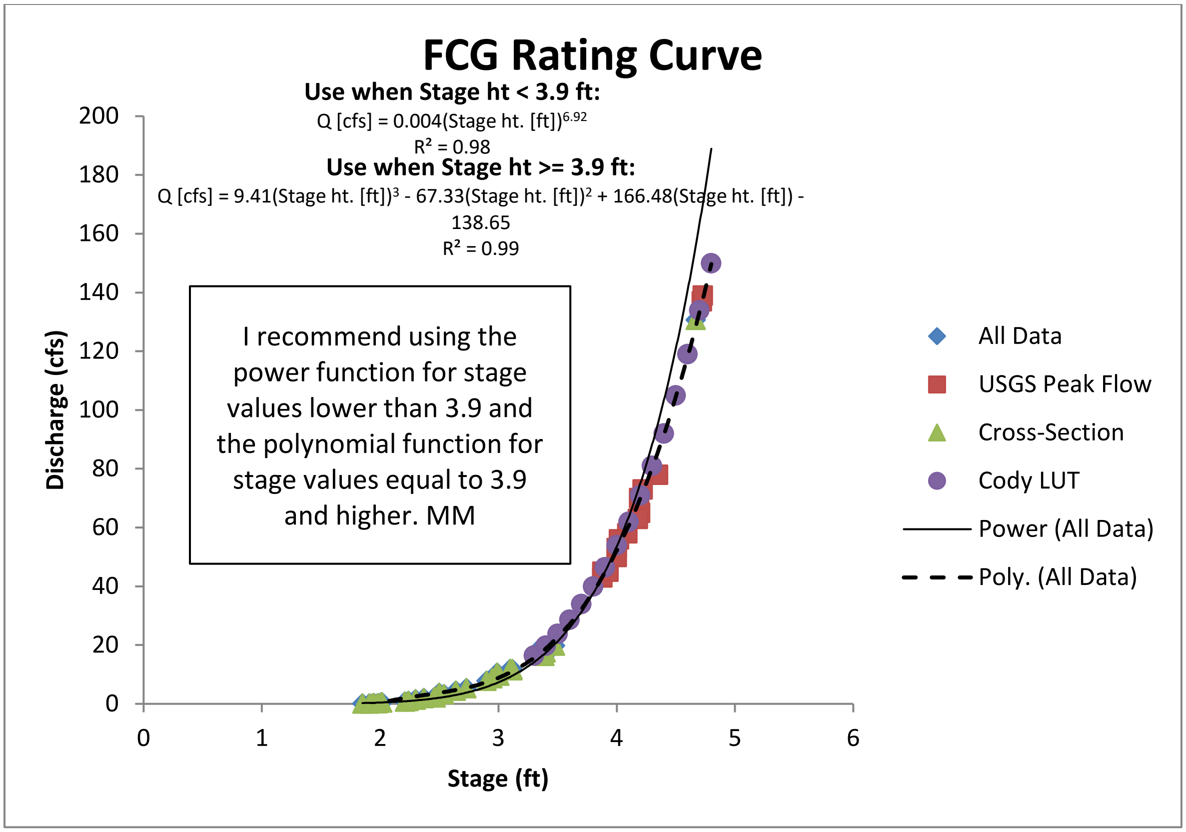

Figure B7. FCG Rating Curve (Menk and Stednick [Appendix II (p. 1.19) in Appendix B1])

Deer Creek Stage-Discharge Relationship

Menk and Stednick developed a rating curve (stage-discharge relationship) for the Deer Creek station using historical high flows as measured by the USGS in the original study, coupled with more recent lower streamflow measurements. Regression analysis between stage and discharge showed a very good fit based on the coefficient of determination. Stream-discharge measurements should continue to be collected to confirm equation stability.

Stage data were used to calculate daily, monthly, and annual streamflow. These runoff values (measured as depth) were compared to on-site precipitation values. Precipitation recorders are located throughout the watershed. However, data quality is generally poor due to missing records or equipment failure. The nearest available long-term precipitation data are for the Alsea Fish Hatchery (AFH) (NOAA 350145), and these data were downloaded. Precipitation at AFH was measured to the 10th of a millimeter (0.1 mm/tip). These data were confirmed by monthly PRISM data (on file at Oregon State University). Water yield efficiency was calculated by dividing runoff depth by precipitation depth. In general, there was good agreement for water yields (runoff/precipitation). When missing, streamflow estimates were made by linear prediction with East Fork Lobster Creek (EFLC) (USGS 14306340 East Fork Lobster Creek near Alsea**,** OR), unless extended periods of record were missing or storm events occurred. Streamflow estimation was based on hydrograph comparisons (Rantz et al. 1982a, b) for short periods of record. Streamflow predictions were for a daily time-step as finer resolution would be too speculative. Streamflow records (DCG_Final_WY1992-2015) include 10-minute, daily, monthly, and annual values.

1. A rating curve was constructed using peak flow data from USGS and cross-sectional measurements made at DCG as shown in Figure B8.

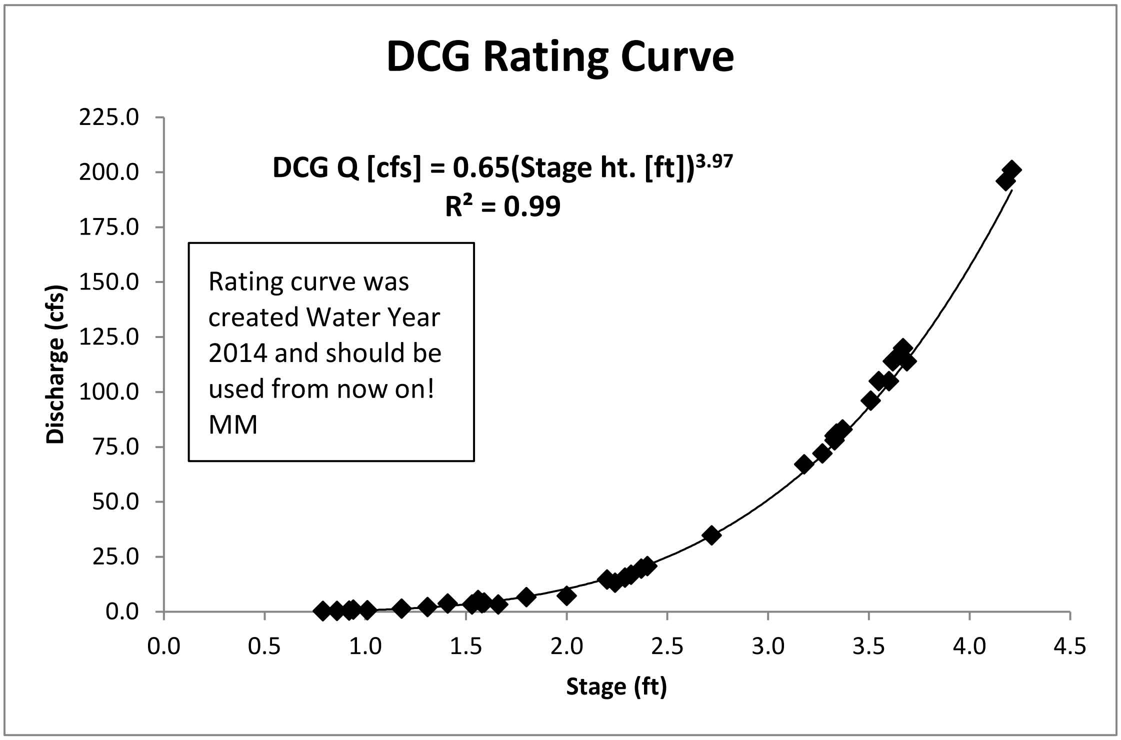

Figure B8. DCG Rating Curve (Menk and Stednick [Appendix I (p. 1.18) in Appendix B1])

   a. When the 10-minute stage data were available, they were converted to a discharge value using Equation B2. The 10-minute data were averaged to get a mean daily value and labeled as raw DCG discharge.

Equation B2: Rating Curve Equation

$$DCG\ Q[cfs] = 0.65(Stage\ ht.[ft])^{3.97}$$

$R^2 = 0.99$

2. When raw DCG discharge was missing, it was predicted.

   a. Linear interpolation or hydrograph comparison was used when possible.

   b. Linear interpolation was not used when there was a precipitation event during the section of missing data or when the section of missing data exceeded 7 days.

   c. If the section of missing data was greater than 7 days, regression Equation B3 was used.

   d. If Equation B3 did not sufficiently predict the missing data, all daily values were set at a constant value.

Equation B3: NBL to DCG Regression

$$DCG\ Q[cfs] = 3.93(NBL\ Q[cfs]) + 0.68$$

$R^2 = 0.94$

3. The mean daily discharge data were converted to a runoff (RO) value using Equation B4.

Equation B4: Runoff Equation

$$Raw\ DCG\ RO[in] = \frac{12 * 86400 * Q[cfs]}{Area[ft^2]}$$

4. The raw DCG RO was summed by month to determine a monthly RO value.
5. On a monthly time-step, raw DCG RO data were compared to RO data from EFLC, and a linear regression was developed to relate the two parameters (Equation B5).

Equation B5: EFLC to DCG Regression

$$DCG\ RO[in] = 0.99(EFLC\ RO[in]) + 1.19$$

$$R^2 = 0.83$$

6. DCG RO was then predicted with Equation B5, and the difference between the predicted DCG RO and raw DCG RO was analyzed.
7. If the value of the difference between the predicted RO and the raw RO was greater than 2 inches/month, the RO was corrected. If the value of the difference between the predicted RO and the raw RO was less than 2 inches/month, then it was assumed that the raw RO value was correct.
8. Once the corrected monthly DCG RO value had been obtained, this value was divided by the raw DCG RO value to come up with a "correction factor" for that month. If no correction was needed, the correction factor is listed as 1. If correction was needed, the factor was scaled to the corrected monthly RO value.

Lower Needle Branch Stage-Discharge Relationship

Menk and Stednick developed a rating curve (stage-discharge relationship) for the lower Needle Branch (NBL) station using historical high flows as measured by the USGS in the original study, coupled with more recent streamflow measurements, taken at lower flows. Regression analysis between stage and discharge may suggest a good fit based on the coefficient of determination. However, deviations from the regression line are apparent. As a result, a lookup table (LUT) was developed, whereby the user inputs the stage to get the corresponding discharge. This table is available in Appendix B1 by Menk and Stednick.

Stage data were used to calculate daily, monthly, and annual streamflow. These runoff values (measured as depth) were compared to on-site precipitation values. Precipitation recorders are located throughout the watershed. However, data quality is generally poor due to missing records or equipment failure (see Recommendations). The nearest available long-term precipitation data are at AFH (NOAA 350145). The AFH data were confirmed by monthly PRISM data (on file at Oregon State University). Water yield efficiency (runoff depth divided by precipitation depth) was calculated, and many months had more runoff than precipitation, indicating an overestimation of streamflow. There are different efficiencies in monthly water yield (wet or dry soil mantle); however, it was determined that streamflow estimates were often too high.

Streamflow corrections were made by simple linear prediction from DCG discharge when possible as it is the closest streamflow gauging station. However, data gaps at DCG dictated the need for another streamflow gauge. Thus, EFLC (USGS 14306340 East Fork Lobster Creek near Alsea, OR) was used as the independent variable. Predictions for short periods of missing records were based on hydrograph comparisons (Rantz et al. 1982a, b), a visual comparison of paired hydrograph shapes. Longer periods of record were estimated by simple linear regressions with EFLC daily streamflow. Streamflow predictions were made for a daily time-step as finer resolution would be too speculative. Streamflow records (NBL_Final_WY1992-2015) include 10-minute, daily, monthly, and annual values.

1. A rating curve was constructed using historic peak flow data from USGS and discharge measurements made at lower flows (Figure B9).

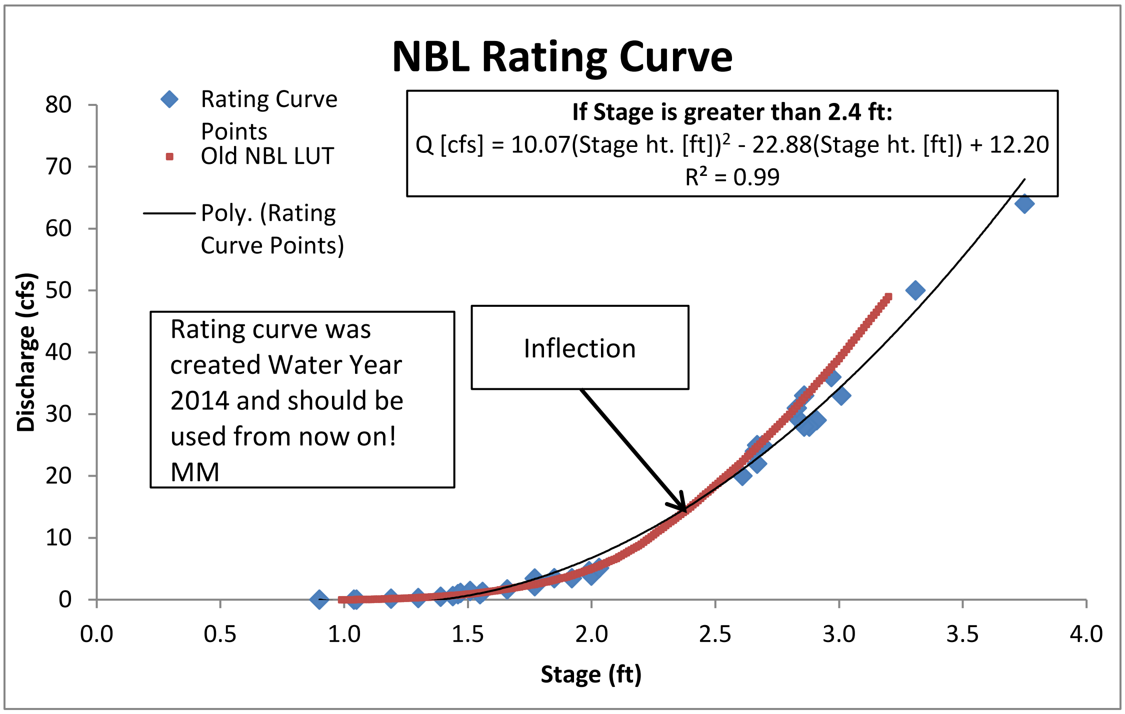

Figure B9. NBL Rating Curve

   a. The LUT for NBL matched the low flows. The peak flows from USGS were fit with a polynomial equation when the stage was >2.4 feet (Equation B6):

Equation B6: High Flow Equation (if stage height is greater than 2.4 feet)

$$NBL\ Q[cfs] = 10.07(Stage\ ht.[ft])^2 - 22.88(Stage\ ht.[ft]) + 12.20$$

$$R^2 = 0.99$$

   b. When the 10-minute stage data were available, they were converted to a discharge value using Equation B6 and the LUT. The 10-minute data were averaged to get a mean daily discharge value and labeled as raw NBL discharge.

2. When raw NBL discharge was missing, it was predicted.

   a. Hydrograph comparison was used except in the cases outlined in (2b) and (2c).

   b. Linear regressions were used when there was a precipitation event during the section of missing data or when the section of missing data did not exceed 7 days.

c. If the section of missing data was greater than 7 days, the entire month was set at a constant discharge value based on the monthly water yield efficiency.

3. The mean daily discharge data were converted to an RO value using Equation B7.

Equation B7:

$$Raw\ NBL\ RO[in] = \frac{12 * 86400 * Q[cfs]}{Area[ft^2]}$$

4. The raw NBL RO was summed by month to determine a monthly RO value.
5. On a monthly time-step, raw NBL RO data were compared to RO data EFLC, and a linear regression was developed to relate the two parameters (Equation B8).

Equation B8:

$$NBL\ RO[in] = 1.07(EFLC\ RO[in]) + 0.91$$

$R^2 = 0.83$

6. Runoff for NBL was then predicted with Equation B8, and the difference between the predicted NBL RO and raw NBL RO was analyzed.
7. If the value of the difference between the predicted RO and the raw RO was greater than 2 inches/month, RO was corrected. If the value of the difference between predicted RO and raw RO was less than 2 inches/month, then it was assumed that raw RO values were correct.
8. Once the corrected monthly NBL RO value had been obtained, this value was divided by the raw NBL RO value to estimate a "correction factor" for that month. If no correction was needed, the correction factor was 1. If correction was needed, the factor was scaled to the corrected monthly RO value.

NBU Stage-Discharge Relationship

There is an 18-inch, 45-degree Plasti-Fab trapezoidal flume installed at NBU. A LUT and a low flow equation were provided by Plasti-Fab where the user inputs the stage to get the corresponding discharge. Stage data were collected every 10 minutes by a pressure transducer located in the flume stilling well. These data were recorded on a data logger and physically downloaded at various intervals, and all files were shared at the water year end. As noted from the field notes, there are no stage corrections resulting from frequent debris removal and/or sediment removal from the flume or when the flume was leaking. The higher stage measurement overestimates streamflow.

Stage data were used to calculate daily, monthly, and annual streamflow. These runoff values (measured as depth) were compared to on-site precipitation values. Precipitation recorders are located throughout the watershed, although data quality is generally poor due to missing records or equipment failure. The nearest available long-term precipitation data for AFH (NOAA 350145) were downloaded. Precipitation is measured to the 10th of a millimeter (0.1 mm/tip) at AFH. These data were further confirmed by monthly PRISM data (on file at Oregon State University). Water yield efficiency was calculated by dividing runoff depth by precipitation depth. Many months had more runoff than precipitation, indicating an overestimation of streamflow. There are different efficiencies in water yield given the wet or dry soil mantle. Nonetheless, it was determined that streamflow estimates were too high.

Once identified, new streamflow estimates were made by linear prediction from NBL discharge when possible as it is the closest streamflow gauging station. Predictions were largely based on hydrograph comparisons (Rantz et al. 1982a, b), a visual comparison of paired hydrograph shapes. Missing data (Needle Branch upper gauging station, NBU) were estimated by comparison to existing streamflow data (Needle Branch gauging station, NBL). Streamflow predictions were for a daily time-step as finer resolution would be too speculative. Thus, if a prediction was necessary, a finer time-step is unavailable. Streamflow records (NBU_Final_WY2007-2015) include 10-minute, daily, monthly, and annual values.

Using the LUT and the low flow equation provided by Plasti-Fab, the 10-minute stage data were converted to a discharge value (Equation B9).

Equation B9: Plasti-Fab Low Flow Equation (if stage height is less than 0.25 feet)

$$NBU\ Q[cfs] = 2.853(Stage\ ht[ft] + 0.13558)^{2.497}$$

   a. When the 10-minute stage data were available, they were converted to a discharge value using Equation B1 and the LUT provided. The 10-minute data were averaged to get a mean daily discharge value and labeled as raw NBU discharge. Lookup tables are included in Appendix B1 by Menk and Stednick.

2. The mean daily discharge data were converted to runoff using Equation B10.

Equation B10: Runoff (RO) Equation

$$Raw\ NBU\ RO[in] = \frac{12 * 86400 * Q[cfs]}{Area[ft^2]}$$

3. When raw NBU runoff was missing, it was predicted.
   a. Linear interpolation was used when possible.
   b. Linear interpolation was not used when there was a precipitation event during the section of missing data or when the section of missing data exceeded 7 days.
   c. If the section of missing data was greater than 7 days, the entire month was set at a constant value.

Equation B11: Preharvest Regression (use 10/1/2006-9/30/2009)

$$NBU\ RO[in] = 1.03(NBL\ RO[in])$$

$R^2 = 0.98$

Equation B12: Postharvest Regression (use 10/1/2009-present)

$$NBU\ RO[in] = 1.08(NBL\ RO[in])$$

$R^2 = 0.94$

4. To account for overestimation of NBU RO, a peak RO equation was developed.

Equation B13: Peak RO Equation

$$NBU\ RO[in]_{Peak} = 0.77(NBL\ RO[in]_{Peak})$$

$R^2 = 0.92$

NOTE: This equation was used on RO values greater than 1 inch.

5. Raw NBU RO data and predicted NBU RO data were summed by month to get a monthly RO value.
6. On a monthly time-step, raw NBU RO and predicted NBU RO were compared to NBL RO, and the differences were analyzed.
7. If the value of the difference between predicted RO and raw RO was greater than 2 inches/month, the raw RO was corrected with Equations B11 and B12. If the value of the difference between the predicted RO and the raw RO was less than 2 inches/month, then it was assumed that the raw RO value was correct.

NBH Stage-Discharge Relationship

The H-flume and gauging station with TTS recorder were installed in December 2008 (2009 water year). Stage data were used to calculate daily, monthly, and annual streamflow. These runoff values (measured as depth) were compared to on-site precipitation values. Precipitation recorders are located throughout the watershed. However, data quality is generally poor due to missing records or equipment failure (see Recommendations). The nearest available long-term precipitation data are at AFH (NOAA 350145) and were recorded by millimeter. The AFH data were confirmed by monthly PRISM data (on file at Oregon State University). Water yield efficiency (runoff depth divided by precipitation depth) was calculated, and many months had more runoff than precipitation, indicating an overestimation of streamflow. There are different efficiencies in monthly water yield (wet or dry soil mantle). However it was determined that streamflow estimates were often too high. Streamflow records (NBH_Final_WY2009-2015) include 10-minute, daily, monthly, and annual values (Appendix B1).

1. Using the LUT provided by Tracom, the 10-minute stage data were converted to a discharge value.
    a. When the 10-minute stage data were available, they were converted to a discharge value using the LUT provided. The 10-minute data were averaged to get a mean daily discharge value and labeled as raw NBH discharge.
2. The mean daily discharge data were converted to RO using Equation B14.

Equation B14: RO Equation

$$Raw\ NBH\ RO[in] = \frac{12 * 86400 * Q[cfs]}{Area[ft^2]}$$

3. Poor correlations of discharge at NBH with NBL, large periods of missing records, combined with overestimation of actual streamflow, effectively precludes using predictive modeling.
4. The raw NBH RO data were summed by month to get a monthly RO value.
5. On a monthly time-step, raw NBH RO data were compared to NBL RO, and the differences were analyzed.
6. If the difference between NBL RO and the raw NBH RO was greater than 2 inches/month, the raw RO was considered inaccurate, and streamflow was not predicted.

Overall Discharge Data Quality Assessment

The Menk and Stednick report (Appendix B1) characterizes the methods and compilation of streamflow data for each watershed, including data going back to 1992 for Deer Creek and lower Needle Branch.

Although the additional data were used to develop rating curves, this quality assurance report was prepared to characterize data quality for the Alsea Watershed Study Revisited, which was initiated in the fall of 2005 and represents data from water years 2006-2015.

As discussed previously, the 10-minute stage data at Flynn Creek were determined to be of poor quality. Therefore, Flynn Creek data were predicted from Deer Creek data and are limited to daily, monthly, and annual discharge values. A discussion of missing Flynn Creek data was not included in the report by Menk and Stednick (Appendix B1). Except for Flynn Creek, each summary report includes a table indicating number of days stage data were missing for each water year.

Table B1 summarizes percent of missing data annually at each site during the Alsea Watershed Study Revisited starting water year 2006. Although stage data were record at NBU for water year 2006, the missing data summary in the Menk and Stednick report did not indicate why these data were not used in the stage-discharge relationships. The flume at NBH was not installed until December 2008, early in the 2009 water year, which explains the high percentage in that year. The upper reaches on Needle Branch (NBU and NBH) had the highest incidence of missing data, likely due to low flow where probes were exposed or debris fouled the sensor.

Table B1. Missing Data Summary

	Missing Data (%)			
Water Year	DCG	NBL	NBU	NBH
2006	24.93	24.11	Stage recorded	Not installed
2007	0.00	0.00	10.41	Not installed
2008	0.00	0.00	0.00	Not installed
2009	15.62	0.00	0.00	30.14
2010	0.82	0.00	4.66	12.60
2011	20.27	0.00	30.14	44.66
2012	6.56	0.00	0.55	0.00
2013	0.00	0.00	0.55	35.62
2014	0.00	0.82	6.03	0.00
2015	0.00	0.00	0.00	0.55
Overall	6.82	2.49	5.81	17.64

The Menk and Stednick report (Appendix B1) characterizes the methods and compiles streamflow data for the five gauges. Overviews of discharge data quality for each station are presented in the following sections.

Flynn Creek (FCG)

Methods and compilation of streamflow data are summarized for FCG for water years 2009-2015 and recorded in an Excel file titled "FCG_Final_WY2009-2015." All FCG streamflow data were predicted with DCG streamflow data. Given the amount of prediction and confidence in the actual streamflow measurements, streamflow data are rated as fair (per Rantz et al. 1982a,b). Streamflow records include daily, monthly, and annual values. Streamflow values can be used for relative comparisons among different years and different gauging locations. These streamflow data cannot be used as a control to estimate annual water yields as affected by timber harvesting.

Deer Creek (DCG)

Methods and compilation of streamflow data are summarized for DCG for water years 1992-2015 and recorded in an Excel file titled "DCG_Final_WY1992-2015." Given the amount of prediction and confidence in the actual streamflow measurements, streamflow data are rated as fair (per Rantz et al. 1982a, b). Streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate stationarity of annual water yields or serve a control watershed without qualification.

As noted from field notes, there are a few stage corrections that are changes in the stage as related to debris removal or sedimentation in the pond. Thus, a higher recorded stage measurement overestimates streamflow.

Lower Needle Branch (NBL)

Methods and compilation of streamflow data are summarized for NBL for water years 1992-2015 and recorded in an Excel file titled "NBL_Final_WY1992-2015." Given the amount of prediction and confidence in the actual stage measurements, streamflow data are rated as fair (per Rantz et al. 1982a, b). Daily streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate stationarity of annual water yields or effects of timber harvesting on streamflow metrics. A series of new recommendations have been made to improve streamflow measurement and water yield quantification.

Upper Needle Branch (NBU)

Methods and compilation of streamflow data are summarized for NBU for water years 2007-2015 and recorded in an Excel file titled "NBU_Final_WY2007-2015." Given the amount of prediction and confidence in the actual stage measurements, these streamflow data are rated as poor (per Rantz et al. 1982a, b). Streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate annual water yields as affected by timber harvesting. New recommendations have been made to improve streamflow measurement and water yield quantification (Appendix B1).

Needle Branch H-flume (NBH)

Methods and compilation of streamflow data are summarized for NBH for water years 2009-2015 and recorded in an Excel file titled "NBH_Final_WY2009-2015." There is a 3-foot Tracom H-flume installed at NBH. A LUT was provided by the flume manufacturer, Tracom, whereby the user inputs the stage to get the corresponding discharge.

Given the amount of prediction and confidence in the actual stage measurements, these streamflow data are rated as poor to very poor (per Rantz et al. 1982a, b). Streamflow values can be used for relative comparisons among different years and different gauging locations. These data cannot be used to estimate annual water yields as affected by timber harvesting.

Overall Recommendations

Menk and Stednick outlined a series of new recommendations to improve streamflow measurement and water yield quantification generally applicable to all stations. Station-specific recommendations are discussed in the sections that follow.

1. A common and readily accessible database needs to be built and maintained. All data need to be uploaded shortly after collection. A common naming/labeling system needs to be implemented. Similarly, field notes, anecdotal observations, and pictures should be included.
2. Standard, nonrecording rain gauges should be placed in and around the study watersheds for additional precipitation data collection and to validate tipping-bucket rain gauges. Alter shields are less important than additional rain gauges.
3. Stream gauging stations all should have "outside" staff gauges (rather than depth to water minus benchmark elevation calculations), including NBH and NBU. The weirs and flumes are not self-maintaining with respect to organic debris and sediment accumulation in the weir ponds or flume itself. Routine maintenance will include removing said debris. However, stage measurements should include "before and after" readings to allow better estimates of stage before debris accumulation. Other than prevention of backwaters impeding downstream flume discharge, downstream channel maintenance efforts are generally not needed.
4. Gauging stations at NBL, DCG, and FCG (all originally built by the USGS) have inside stage gauges located in their stilling well. These stage readings should be included in routine maintenance of the gauging station. This confirms the stage reading and a responsive hydraulic connection between the stilling well and inlet pipes (stream level). See a proposed discharge measurement form in Appendix F (p. 1.23) in Appendix B1.
5. There should be more site visits to gauging stations and/or increased recording of stage during site visits. Stage values are rarely corrected or adjusted, but stage shifts are recognized at all streamflow gauging stations. Stage notes can be collected on the proposed discharge form in Appendix F (p. 1.23) in Appendix B1.
6. All weirs and flumes are subject to leakage. It is advised that a small amount of fluorescein dye be injected into the upstream channel, especially during low flows, to identify structure leakage. Maintenance can include caulking, mortar, and/or waterproof epoxy.
7. Increased streamflow measurements should be made to build better rating curves for all stations. The rating curve (stage-discharge relationship) should not be considered constant. All stations are subject to channel shape changes that will affect the rating curve. The lower portion of the rating curve is subject to change. Offsets are rarely addressed in the streamflow reduction. Units are often problematic, whereby streamflow may be measured as meters per second and then incorrectly converted to feet per second. See the proposed discharge measurement form in Appendix F (p. 1.23) in Appendix B1. We advise that each discharge measurement be plotted to assess rating curve functionality and consistency. A point to the left of the curve will show backwater conditions. Conversely, a point to the right of the curve may show a steeper energy slope, as on a rising limb. Each gauging station has a zero-flow stage that needs to be included in the rating curve.

Flynn Creek Recommendations

A decision on Flynn Creek needs to be made as to its added value for streamflow monitoring. A second pressure transducer was placed in the Flynn Creek weir pond in 2007 to record stage values. Using two stage values, near the weir and at the head of the weir pond, would allow calculation of a water slope to estimate discharge as a step-backwater. These data, or the second pressure transducer, have apparently been lost. Better discharge estimates would improve the rating curve. The current rating curve is very poor. We will be hard-pressed to re-create past streamflow values and will have to develop a predictive equation, probably from Deer Creek, as precipitation data are inconsistent between stations, and storm event precipitation records are also frequently missing.

The gauging station at FCG (all originally built by the USGS) has an inside stage gauge located in the stilling well. These stage readings should be included in routine maintenance of the gauging station (see note 4 in section titled “Overall Recommendations”).

Deer Creek Recommendations

The gauging station at DCG has an inside stage gauge located in the stilling well. These stage readings should be included in routine maintenance of the gauging station (see note 4 in section titled “Overall Recommendations”).

Lower Needle Branch Recommendations

The gauging station at NBL has an inside stage gauge located in the stilling well. These stage readings should be included in routine maintenance of the gauging station (see note 4 in section titled “Overall Recommendations”).

Upper Needle Branch Recommendations

Stream gauging stations all should have “outside” staff gauges (rather than depth to water minus benchmark elevation calculations), including NBU (see note 3 in section titled “Overall Recommendations”).

Needle Branch H-flume Recommendations

Stream gauging stations all should have “outside” staff gauges (rather than depth to water minus benchmark elevation calculations), including NBH (see note 3 in section titled “Overall Recommendations”).

Evaluation of Data Logger Water Quality Measurements

As discussed in the section titled “Data Collection Equipment and Procedures,” turbidity, temperature, and conductivity measurements were recorded along with stage data. Instrument quality control specifications are discussed herein. Data validation is discussed for each parameter in a separate appendix.

Data Logger Turbidity Data Validation

Turbidity was measured using an OBS-3-L turbidity probe and recorded by the CR10X data logger. The OBS-3 turbidity sensor uses an optical backscatter method to measure turbidity in the range of 0 to 4,000 formazin turbidity units (FTU). The OBS-3 manufacturer’s specifications are shown in Table B2.

Table B2. OBS-3 Turbidity Sensor Manufacturer's Specifications

Parameter	Specification
Nonlinearity of turbidity	2% (formazin, 0 to 2,000 FTU)
Drift	<5% per year
Settling time	<1 s
Input voltage	9-16 Vdc
Maximum depth	500 m (1,640.5 ft)
Infrared wavelength	875 nm

Teledyne ISCO samplers and turbidity probes were removed from the system for necessary maintenance and storage during the dry season. Field procedures indicated the turbidity probe calibration was to be checked with a calibration standard prior to storage and before deployment.

As discussed previously, data logger stage and turbidity data were plotted to look for obvious fouling of the probe or instrument malfunctions. Suspicious data were flagged according to the specifications given in the section titled "Turbidity Correction."

Identifying Suspicious Turbidity Data

Suspicious data are those measurements that do not appear to fit some expected value. Suspicious data can be identified by considering either the measurements taken just before or after the measurement in question or the conditions measured by other instruments.

Plots are useful tools to identify suspicious stage height and turbidity measurements. Suspicious data can be more obvious when viewed graphically instead of in table form. Following are some examples of graphically obvious, suspicious data:

- Turbidity values were remaining fairly stable over the course of several hours/days etc., and then suddenly jumped up for one 10-minute sampling interval before dropping to the original value in the next interval. This was likely caused by debris obstruction that washed away or an animal that passed close to the sensor.
- Turbidity values during a storm suddenly drop to low (<15) values. Likely a sensor boom pushed out of the water.
- Turbidity values spike during the recession limb of a storm, likely caused by debris floating in the channel catching on the sensor boom.
- Turbidity values slowly creep upward with no storm suggested in hydrograph. Likely, organic film accumulated on the sensor or sensor drift.
- Prolonged measurements of turbidity values are higher than expected for that stream. The sensor may have been buried beneath stream material or may have debris caught on it.
- There is a sudden shift in stage height. This may be a pressure transducer offset in the TTS code being changed by a field technician. There may also be frogs, salamanders, or debris obstructing the stilling well.

If the suspicious data triggered an ISCO sample, the suspended sediment concentration (SSC) analysis may help isolate those samples that were correct measurements of stream conditions. If in doubt and an ISCO sample exists from that sampling interval, wait for the analysis before changing the raw data. Suspicious data can also be identified in the Excel files. This often consists of making sure there is continuity in these data. One or two sampling intervals may be missing from either end of a block of downloaded data.

Turbidity Correction

The corrections to suspicious turbidity data like those explained in the previous section's examples may be simple. Because these blips often occur for a short amount of time, turbidity values can be corrected to the values before and after the blip happened. However, there are suspicious data that are more complicated to correct. Therefore, it is beneficial to wait for the SSC analysis (if the ISCO took a sample) before making changes to turbidity values. Once the SSC analysis has been completed, the relationship between turbidity and SSC can be used to predict a more correct turbidity value.

If the ISCO did not take a sample and no SSC analysis is available, then using the stage height can be a valuable tool. Each TTS station has some minimum height set below which the ISCO will not sample. At the end of a hydrological year, the minimum stage is used as a threshold of any suspicious turbidity data. For example, if a turbidity value of 50 NTU was measured when the stream was below the minimum sampling stage, then that turbidity value is corrected to the "background" turbidity of that stream in a nonstorm condition.

Turbidity usually spikes just before, or coincides with, the peak of the storm hydrograph. Beyond the peak, a stream has less energy to transport sediment than was available at the time of the peak. Thus, if the turbidity value suddenly spikes during the recession limb of a storm, then it is likely that a piece of debris was stuck on the sensor or perhaps the stream bank collapsed or a tree fell on top of the sensor.

Appendix C discusses the quality of sediment and turbidity data collected for the Alsea Watershed Study Revisited.

Temperature Data Validation

Temperature and conductivity were measured using a CS547A dual temperature and conductivity probe. The manufacturer's temperature specifications are given in Table B3. The temperature was factory tested using a National Institute of Standards and Technology traceable standard with ±0.25% accuracy. The quality plan indicated that field checks were to be conducted every 3 months during deployment and postdeployment. Checks were to be made using audit thermometers with accuracy of ±0.5°C and resolution of ±0.2°C following procedures described in the Oregon Watershed Enhancement Board's guidebook (OWEB, 1999). A discussion of temperature data quality is presented in Appendix D.

Table B3. CS547A Temperature and Conductivity Probe Manufacturer's Specifications

Parameter	Specification
Temperature range	0-50°C
Temperature accuracy	Error ±0.4°C

Evaluation of Conductivity Data

The CS547A manufacturer's conductivity specifications are given in Table B4. The CS547A was shipped with a cell constant calibrated in a 0.01 molar potassium chloride (KCl) solution at 25°C ±0.05°C. The solution has an electrical conductivity of 1.408 mS cm^{-1}. In accordance with the quality assurance project plan, conductivity was to be validated quarterly using a KCL standard. At the time of publication, conductivity data had not been validated.

Table B4. CS547A Temperature and Conductivity Probe Manufacturer's Specifications

Parameter	Specification
Conductivity range	Approximately 0.005-7 mS cm^{-1}
Conductivity accuracy	
KCl and Na_2SO_4	±5% of reading 0.44-7 mS cm^{-1}
$NaHCO_3$ and NaCl standards at 25°C	±10% of reading 0.005-0.44 mS cm^{-1}

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APPENDIX C
SEDIMENT AND TURBIDITY DATA QUALITY

Synopsis Prepared by Terry Bousquet, NCASI, and Amy Simmons and Alex Irving, Oregon State University
Field Sampling and Turbidity Threshold Sampling Data Collection Conducted by Cody Hale and David Leer, Oregon State University
Sediment Analysis and Database Management by Amy Simmons, Oregon State University
Data Validation and Interpretation by Jeff Hatten and Alex Irving, Oregon State University

Introduction

Suspended sediment samples were collected at Deer Creek (DCG), Flynn Creek (FCG), and upper (NBU) and lower Needle Branch (NBL) gauges as part of the Alsea Watershed Study Revisited. Sample collection was triggered by a turbidity threshold sampling (TTS) protocol (Eads and Lewis 2003) that uses turbidity thresholds in conjunction with stage data to activate sample collection via a Teledyne ISCO sampler. Both turbidity and suspended sediment are measured using standard operating procedures at the Oregon State University, Department of Forest Engineering Resources & Management Forest Hydrology Laboratory (see Attachment B in Quality Assurance Project Plan available from: https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf). The next section describes the sample collection process and threshold levels used to trigger sample collection at each site. Identifying and correcting suspicious TTS turbidity data is discussed in the third section, including the relationship to Teledyne ISCO sample collection. Laboratory procedures and quality assurance conducted for suspended sediment and laboratory turbidity measurements are discussed in the last section.

Collection of Suspended Sediment Samples

TTS equipment and sample collection via a Teledyne ISCO 3700 sampler are described in detail in Appendix B. Table C1 shows the rising and falling turbidity threshold values and corresponding minimum stage values used to trigger sample collection at each of the gauging stations throughout the study area. The threshold number is the number out of total thresholds associated with the set of threshold values for either rising or falling values. The threshold type identifies whether the turbidity value is a rising or falling threshold. The minimum turbidity threshold values assigned to each gauging station and the dates these thresholds were implemented are given in the last two rows of the table. The stage value represents the minimum stage in feet that would allow a turbidity sample to be triggered if the turbidity criteria were also met. Turbidity thresholds are the same at each gauging station, but minimum stage levels vary.

Table C1. Turbidity and Stage Threshold Values for Each Gauging Station

Threshold Number	Threshold Type	Turbidity (NTU) DCG	FCG	NBL	NBU
1	Rising	0	0	0	0
2	Rising	20	20	20	20
3	Rising	35	35	35	35
4	Rising	55	55	55	55
5	Rising	83	83	83	83
6	Rising	118	118	118	118
7	Rising	162	162	162	162
8	Rising	216	216	216	216
9	Rising	281	281	281	281
10	Rising	357	357	357	357
11	Rising	446	446	446	446
12	Rising	549	549	549	549
13	Rising	667	667	667	667
14	Rising	800	800	800	800
15	Rising	950	950	950	950
16	Rising	9,999	9,999	9,999	9,999
1	Falling	1,000	1,000	1,000	1,000
2	Falling	881	881	881	881
3	Falling	773	773	773	773
4	Falling	673	673	673	673
5	Falling	583	583	583	583
6	Falling	501	501	501	501
7	Falling	427	427	427	427
8	Falling	361	361	361	361
9	Falling	302	302	302	302
10	Falling	249	249	249	249
11	Falling	200	200	200	200
12	Falling	175	175	175	175
13	Falling	135	135	135	135
14	Falling	100	100	100	100
15	Falling	76	76	76	76
16	Falling	63	63	63	63
17	Falling	43	43	43	43
18	Falling	27	27	27	27
Stage (ft)	Minimum	1.45	2.4	1.4	0.25
Date	Start	10/19/2006	11/3/2006	11/3/2006	11/1/2006

The number of samples collected in any one episode varies depending on the amount and duration of rainfall events with a maximum sampler capacity of 24 samples. A summary of the number of samples collected and submitted to the laboratory for suspended sediment analyses in each water year is presented in Table C2. Sampling was only conducted once at the Needle Branch H-flume (NB-7) site in 2011. Sampling at NBU began in 2009.

Table C2. Count of Samples Analyzed for Suspended Sediment Analyses by Site Name

Site Name	Water Year 2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
DCG	197	179	154	179	195	57	295	343	132	200
FCG	217	169	175	109	179	60	377	309	165	178
Needle Branch H-flume						15				
NBL	97	155	133	60	124	56	147	262	2	115
NBU				24	8	21	170	83	32	17
Annual total	511	503	462	372	506	209	989	997	331	510

Suspicious Turbidity Data: Identification and Correction

Identifying Suspicious Data

Suspicious data are those measurements that do not appear to fit some expected value. Suspicious data can be identified by considering either the measurements taken just before or after the measurement in question or the conditions measured by other instruments.

Plots are useful tools to identify suspicious stage height and turbidity measurements. Suspicious data can be more obvious when viewed graphically instead of in table form. Following are some examples of graphically obvious, suspicious data:

1. Turbidity values were remaining fairly stable over the course of several hours/days, etc., and then suddenly jumped up for one 10-minute sampling interval before dropping to the original value in the next interval. This may have been caused by a debris obstruction that washed away or an animal that passed close to the sensor.

2. Turbidity values during a storm suddenly drop to low (<15) values. A sensor boom was pushed out of the water.

3. Turbidity values spike during the recession limb of a storm. Debris floating in the channel got caught on the sensor boom.

4. Turbidity values slowly creep upward with no storm suggested in a hydrograph. This may be due to organic film accumulating on the sensor or sensor drift.

5. Prolonged measurements of turbidity values are higher than expected for a stream. The sensor may have been buried beneath stream material or may have debris caught on it.

6. There is a sudden shift in stage height. A pressure transducer offset in the TTS code was changed by the field technician. This may also be caused by frogs, salamanders, or debris obstructing the stilling well.

If the suspicious data triggered a Teledyne ISCO sample, the suspended sediment concentration (SSC) analysis may help isolate those samples that were correct measurements of stream conditions. If in doubt and a Teledyne ISCO sample existed from that sampling interval, we waited for the analysis before changing the raw data.

Suspicious data could also be identified in the Excel files. Identification often consisted of making sure there was continuity in the data. One or two sampling intervals may be missing from either end of a block of downloaded data.

Turbidity Corrections

The corrections to suspicious turbidity data such as in examples 1 through 5 in the previous subsection may be simple. Because these blips often occur for a short amount of time, turbidity values can be corrected to the values before and after the blip occurred. However, there are suspicious data that are more complicated to correct. Therefore, it was beneficial to wait for the SSC analysis (if the Teledyne ISCO took a sample) before making changes to turbidity values. Once the SSC analysis has been completed, the relationship between turbidity and SSC can be used to predict a more correct turbidity value.

If the Teledyne ISCO did not take a sample and no SSC analysis was available, then using the stage height can be a valuable tool. Each TTS station has some minimum height set below which the Teledyne ISCO will not sample. At the end of a hydrological year, the minimum stage was used as a threshold of any suspicious turbidity data. For example, if a turbidity value of 50 were measured when the stream was below the minimum sampling stage, then that turbidity value was corrected to the “background” turbidity of that stream in a nonstorm condition.

Turbidity usually spikes just before, or coincides with, the peak of the storm hydrograph. Beyond the peak, the stream has less energy to transport sediment than was available at the time of the peak. Thus, if the turbidity value suddenly spikes during the recession limb of the storm, then it was likely that a piece of debris was stuck on the sensor or perhaps the stream bank collapsed or a tree fell on top of the sensor.

Each download of data from the data logger was treated as a set of data. This was generally 1 to 3 weeks of data, but the range was sometimes shorter or longer. For each set of data, stage and turbidity are graphed together and examined for consistency between the two measurements. Turbidity values should rise and fall closely with the stage values.

Turbidity measurements are recorded on a 10-minute interval. The maximum number of measurements during a year was 52,704 and 52,560 during leap years and nonleap years, respectively. The percent completeness values of field turbidity data (including synthesized data) are reported in Table C3 by site name and water year. The average percent completeness of field turbidity for water years 2007-2014 at the sampling sites ranges from 77.3% to 89.7%.

Table C3. Percent Completeness of Field Turbidity Data by Site Name

Water Year	DCG	NBU	NBL	FCG
2007	83.0%	86.9%	97.5%	94.7%
2008	93.8%	93.3%	95.7%	84.6%
2009	89.1%	98.7%	96.6%	90.7%
2010	78.3%	82.2%	94.7%	65.4%
2011	56.0%	38.9%	93.4%	50.8%
2012	62.8%	87.4%	82.1%	59.9%
2013	83.9%	90.2%	79.4%	84.8%
2014	99.5%	93.3%	78.0%	87.2%
Overall	80.8%	83.9%	89.7%	77.3%

If a random turbidity spike occurred (a few data points in a row), the spike was removed, and new data were synthesized. An example would be 9, 8, 10, 9, 9, 50, 900, 900, 800, 9, 9, 8. The 50, 900, 900, 800 would be removed (and put in the "removed turb data" column) and synthesized new data to 9, 9, 9, 9. These points were also flagged as "r, s" (removed, synthesized). The percentage of synthesized field turbidity data was reported in Table C4. For water years 2007-2014, the percentage of synthesized field turbidity ranges from 0.8% to 2.1%.

Table C4. Percentage of Synthesized Field Turbidity Data by Site Name

Water Year	DCG	NBU	NBL	FCG
2007	0.2%	0.0%	0.2%	0.3%
2008	0.6%	0.0%	0.1%	0.0%
2009	1.8%	0.0%	0.1%	0.0%
2010	0.0%	0.0%	0.0%	0.0%
2011	0.4%	0.0%	0.0%	0.0%
2012	0.0%	0.6%	0.2%	3.6%
2013	0.7%	0.4%	2.7%	0.4%
2014	7.8%	15.5%	2.8%	2.8%
Overall	1.4%	2.1%	0.8%	0.9%

If a larger section of "bad" data occurred, generally five or more, that section was removed (and put in the "removed turb data" column) but not synthesized, as there was low confidence in assuming what these data should have been. These data would be flagged as "r" (removed). Sometimes this range could span a week or more. The percentage of removed or missing field turbidity data is reported in Table C5. For water years 2007-2014, the average percentage of removed/missing field turbidity ranged from 10.3% to 22.7%.

Table C5. Percentage of Removed or Missing Field Turbidity Data by Site Name

Water Year	DCG	NBU	NBL	FCG
2007	16.9%	12.6%	2.6%	5.3%
2008	6.2%	6.7%	4.3%	15.4%
2009	10.9%	1.3%	3.4%	9.3%
2010	21.7%	17.8%	5.3%	34.6%
2011	44.0%	61.1%	6.4%	49.1%
2012	37.2%	12.6%	18.0%	40.0%
2013	16.1%	9.8%	20.2%	15.2%
2014	0.5%	6.7%	22.0%	12.8%
Overall	19.2%	16.1%	10.3%	22.7%

Deer Creek's turbidity values occasionally slowly drifted up. This was most likely due to algae buildup. To correct this, and be aligned with Cody Hale's methods, a drift correction was applied to the turbidity values from the point they started to drift up until the next maintenance or sensor cleaning. The formulas for doing this are in the data.

One of the biggest problems was making sure that the physical water samples that were submitted to Oregon State University's Department of Forest Engineering Resources & Management Forest Hydrology Laboratory (Skaugset laboratory) for SSC analysis correctly corresponded with the dump (collection number) and sample number in the TTS data. Each set of TTS data was compared to the SSC records. Any discrepancy was fixed. This was very important so that each sample's SSC can be correlated to the corresponding turbidity value.

Turbidity and Suspended Sediment Data Quality Review

The laboratory measures turbidity in each sample to be processed for suspended sediment using a Hach 2100P turbidimeter. The turbidimeter has a range of 0-1,000 NTU, accuracy of ±2%, and resolution of 0.01 on the lowest range. The standard operating procedure stipulates that turbidity blank values are to be below 0.15 NTU before proceeding with analyses. The turbidity meter is checked against three Gelex secondary standards (0-10, 0-100, 0-1,000 NTU) for each sample batch and must be within the correct range prior to sample analysis.

Sediment analyses were conducted at Oregon State University's Department of Forest Engineering Resources & Management Forest Hydrology Laboratory following the protocols described in *Laboratory Procedures for Determining Suspended Sediment Concentration* (Oregon State University 2013; archived version available in Attachment B in Quality Assurance Project Plan available from: https://www.ncasi.org/wp-content/uploads/2019/02/AlseaQAPP10-01-07.pdf). Microscales were used to weigh filters. Macroscales were used to weigh sample bottles of suspended sediment. Scales were calibrated weekly, and results were recorded in a laboratory notebook and recalibrated as necessary. A method blank was prepared with deionized (DI) water and processed identically as samples with each set of 12 samples. Samples were vacuum filtered using a 1.5-µm glass fiber filter paper (Whatman 934-AH). Filters were dried in a laboratory oven set at 105°C for 24 hours. Filters were cooled in a desiccant cabinet for at least 10 minutes prior to weighing. Desiccant was replaced when too much moisture was absorbed, and it turned pink. The standard operating procedure presents Equation E1 for calculating SSC.

Equation E1: Equations for Computation of SSC

SSC (mg/L) = (Mass of sediment × 1,000,000)/Actual volume of sample (mL)

where

Mass of sediment (g) = Mass of sediment and filter (g) – Mass of oven-dried filter (g)
Calculated volume (g) = Mass of bottle and sample (g) – Mass of bottle (g)
Actual mass of water in sample (mL) = (Calculated volume [g] – Mass of sediment [g]) × Mass of sediment/particle density (2.65 g) converted to mL = (Mass of sediment [g]/2.65 g) × (1 mL/g)
Actual volume of sample (mL) = Actual mass of water in sample (mL) + Mass of sediment converted to mL

Notes:

Assumption: density of water is 1gm/mL; therefore, 1 g of water has a volume of 1 mL
Assumption: particle density = 1 cc of soil = 2.65 g

Suspended Sediment Data Validation

As mentioned previously, the number of samples collected in any one episode varied depending on amount and duration of rainfall events with a maximum sampler capacity of 24 samples per event. Sediment data were flagged for suspicious results or if there were noted issues with the data. Data were flagged for suspicious suspended sediment values, high suspended sediment with corresponding low laboratory turbidity, interferences (e.g., pebbles, large debris, or insects not removed prior to weighing), field collection issues, empty samples that were submitted to the laboratory, or laboratory implementation issues. Table C6 summarizes the percentage of samples flagged in each water year for the three main gauging stations. During water years 2006-2015, 334 SSC samples (6.2% of samples) had a negligible mass of sediment. For all gauging stations, the overall number of flagged samples was 250/5,390 (4.6%).

Table C6. Flagged Suspended Sediment Analyses at Main Gauging Stations

	Number Flagged/Sample Count (%)		
Water Year	DCG	FCG	NBL
2006	5/197 (2.5%)	3/217 (1.4%)	0/97 (0%)
2007	8/179 (4.5%)	4/170 (2.4%)	19/155 (12.3%)
2008	15/154 (9.7%)	11/175 (6.3%)	0/133 (0%)
2009	1/179 (0.6%)	0/109 (0%)	1/60 (1.7%)
2010	1/195 (0.5%)	7/179 (3.9%)	1/124 (0.8%)
2011	0/57 (0%)	1/60 (1.7%)	0/56 (0%)
2012	8/295 (2.7%)	51/377 (13.5%)	0/147 (0%)
2013	6/343 (1.7%)	24/309 (7.8%)	2/262 (0.8%)
2014	49/132 (37.1%)	27/165 (16.4%)	0/2 (0%)
2015	1/200 (0.5%)	0/178 (0%)	0/115 (0%)
Overall	94/1,931 (4.9%)	128/1939 (6.6%)	23/1151 (2%)

Conclusion

The overall quality of field turbidity data for the Alsea Watershed Study Revisited was good. The average percent completeness of field turbidity measurements ranges from 77.3% to 89.7% for water years

2007-2014 at the TTS sampling sites. Suspicious and erroneous field turbidity data have been removed and flagged. When only a few continuous turbidity measurements are removed, they are usually synthesized. The average percentage of synthesized field turbidity ranges from 0.8% to 2.1% for the sampling sites.

The overall quality of suspended sediment data for the Alsea Watershed Study Revisited was very high. For all the gauging stations during water years 2006-2015, the number of flagged samples was 250 samples out of 5,390 samples (4.6%). Data were flagged for suspicious suspended sediment values, high suspended sediment with corresponding low laboratory turbidity, interferences (e.g., pebbles, large debris, or insects not removed prior to weighing), field collection issues, empty samples that were submitted to the laboratory, or laboratory implementation issues.

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Oregon State University. 2013. *Laboratory Procedures for Determining Suspended Sediment Concentration*. Corvallis OR: Oregon State University, Department of Forest Engineering.

APPENDIX D

STREAM TEMPERATURE DATA QUALITY

Synopsis Prepared by Terry Bousquet, NCASI, and Amy Simmons, Oregon State University
Thermistor Field Deployment and Data Collection by Jeff Light, Plum Creek Timber Company
Data Validation by Jeff Light, Plum Creek Timber Company, and Dr. Kevin Bladon and Dr. Nicholas Cook, Oregon State University

Introduction

Stream temperature was being measured in three ways during the study. As discussed in Appendix C, temperature was recorded year-round along with conductivity using CS547A-L probes and electronic data loggers at 10-minute intervals at each gauging station. The quality of temperature data determined using stream temperature data loggers deployed at various synoptic sites in the summer months (approximately June-September) in each watershed (Deer Creek, Flynn Creek, and Needle Branch) is described herein for data collected 2006 through 2011. Data collected from 2012-2016 are not included in this analysis but were collected and data reside with Oregon State University. Use of that data may require additional quality control procedures as outlined here. An archived version of stream temperature data from 2006 to 2012 associated with Bladon et al. (2016) can be found in Oregon State University's scholar's archive (https://ir.library.oregonstate.edu/concern/datasets/ff365c69j).

Maps showing deployment locations are presented in Appendix A. Thermistor deployment schedules are discussed in the next section, and temperature quality assurance/quality control assessments are discussed in the third section. Temperature was also recorded at 30-minute intervals when dissolved oxygen was measured at gauging stations. These data quality assessments are discussed in Appendix E.

Temperature Data Logger Deployment at Synoptic Sites

Onset HOBO TidbiT v2 water temperature data loggers (thermistors) were deployed to measure temperature at 30-minute intervals at various sites on Needle Branch and Flynn Creek and at the gauging station on Deer Creek. The thermistor array was reduced at Deer Creek after 2006 because Deer Creek was intended as a backup site with a minimal level of monitoring, not a focus of this study. This site was measured more broadly in 2006-2008 to compare contemporary vs. historical temperatures. In 2007 and 2008, a different temperature data logger model (Onset HOBO Pro v2) was deployed in Needle Branch, and nearly all units failed to download data. These data loggers were returned to Onset where most of the data were retrieved. In 2014 and 2015, the density of thermistors deployed along the Needle Branch main stem was increased to examine the longitudinal pattern of warming and cooling (see Figures A1-A3 in Appendix A). Replicate sensors were deployed periodically to ensure data integrity. For locations with replicate sensors, data from both sensors are included in this data summary.

For deployment, thermistors were placed in deeper water (usually pools) where current was strong. Thermistors were tied to rocks with zip-ties and tethered to stream-bank vegetation using 10-gauge haywire. A rock cairn was built over each logger to hold it in place and to shield it from potential direct sunlight. Cairns were constructed to allow good flow over the thermistors.

A summary of deployment dates, grouped according to watershed basin and water year, is presented in Table D1 for water years 2006-2015. The number of thermistors deployed in each watershed, number with reportable data, and number of sites where data were deleted are shown in the table. Dates presented show the earliest deployment date and latest retrieval date of all thermistors in each watershed. Except for the 2010 water year when thermistors were deployed in July, sensors were deployed in June and retrieved in September. Very few records were deleted.

Table D1. Summary of Thermistor Deployment for Stream Temperature: Water Years 2006-2015

	Deer Creek	Flynn Creek	Needle Branch
2006			
Thermistors deployed	16	15	13
Thermistors reported	15	14	9
Thermistor data deleted	1	1	4
Date deployed	6/14/2006	6/14/2006	6/14/2006
Date retrieved	9/19/2006	9/19/2006	9/19/2006
2007			
Thermistors deployed	7	18	10
Thermistors reported	8	13	11
Thermistor data deleted	2	1	1
Date deployed	6/1/2007	6/1/2007	6/6/2007
Date retrieved	9/24/2007	9/24/2007	9/11/2007
2008			
Thermistors deployed	11	13	11
Thermistors reported	11	12	11
Thermistor data deleted	0	0	0
Date deployed	6/14/2008	6/14/2008	6/10/2008
Date retrieved	11/3/2008	10/19/2008	12/14/2008
2009			
Thermistors deployed	1	12	12
Thermistors reported	1	12	12
Thermistor data deleted	0	0	0
Date deployed	6/5/2009	6/5/2009	6/2/2009
Date retrieved	9/30/2009	9/30/2009	9/30/2009
2010			
Thermistors deployed	1	12	11
Thermistors reported	1	12	11
Thermistor data deleted	0	0	0
Date deployed	7/13/2010	7/13/2010	7/13/2010
Date retrieved	9/6/2010	9/6/2010	9/6/2010
2011			
Thermistors deployed	1	12	11
Thermistors reported	1	11	11
Thermistor data deleted	0	1	0
Date deployed	6/23/2011	6/22/2011	6/23/2011
Date retrieved	9/19/2011	9/18/2011	9/20/2011

	Deer Creek	Flynn Creek	Needle Branch
2012			
Thermistors deployed	1	12	11
Thermistors reported	1	12	11
Thermistor data deleted	0	0	0
Date deployed	6/28/2012	6/26/2012	6/26/2012
Date retrieved	9/30/2012	10/3/2012	10/3/2012
2013			
Thermistors deployed	1	12	12
Thermistors reported	1	12	12
Thermistor data deleted	0	0	0
Suspect data (%)			
Date deployed	6/4/2013	6/5/2013	6/3/2013
Date retrieved	9/17/2013	9/17/2013	9/17/2013
2014			
Thermistors deployed	1	12	40
Thermistors reported	1	12	40
Thermistor data deleted	0	0	0
Date deployed	6/19/2014	6/19/2014	6/19/2014
Date retrieved	9/11/2014	9/11/2014	9/11/2014
2015			
Thermistors deployed	2	12	51
Thermistors reported	2	12	51
Thermistor data deleted	0	0	0
Date deployed	6/11/2015	6/10/2015	6/8/2015
Date retrieved	9/21/2015	9/21/2015	9/21/2015

Quality Assurance/Quality Control Assessment

HOBO TidbiT temperature thermistor sensor specifications are shown in Table D2. Prior to deployment each year, all thermistors were tested for accuracy by examining cooling rates and absolute temperature values after submersion in an ice bath, per instructions from Onset. Thermistors that failed to launch or download or that showed evidence of inaccurate readings were not deployed. Outright failure of HOBO TidbiT thermistors and drift in accuracy were rare.

Table D2. Onset HOBO TidbiT Temperature Sensor Specifications

Parameter	Specification
Operation range	−20° to 70°C (−4° to 158°F) in air
Maximum sustained temperature	30°C (86°F) in water
Accuracy	0.2°C over 0-50°C (0.36°F over 32-122°F)
Resolution	0.02°C at 25°C (0.04°F at 77°F)
Response time	5 minutes in water; 12 minutes in air moving 2 m/s; 20 minutes in air moving 1 m/s (typical to 90%)
Stability (drift)	0.1°C (0.18°F) per year

Patterns of daily temperatures across a season were subjectively evaluated for suspect data using original half-hourly plots from a HOBO TidbiT download. In areas where there were marked deviations from the “rhythm” the data expressed or if sharp peaks were found, data were cross-checked with other sites in the area or weather data to see if suspect data correlated with a day or period that was unusually hot or cold to determine whether these data were valid. When the suspect data were due to drying during or at the end of the season (after mid-August), the pattern looked more like air temperatures (higher and lower daily maxima) than water temperature. These data were flagged where appropriate. Figure D1 is an example plot of the NBU-g data from 2011.

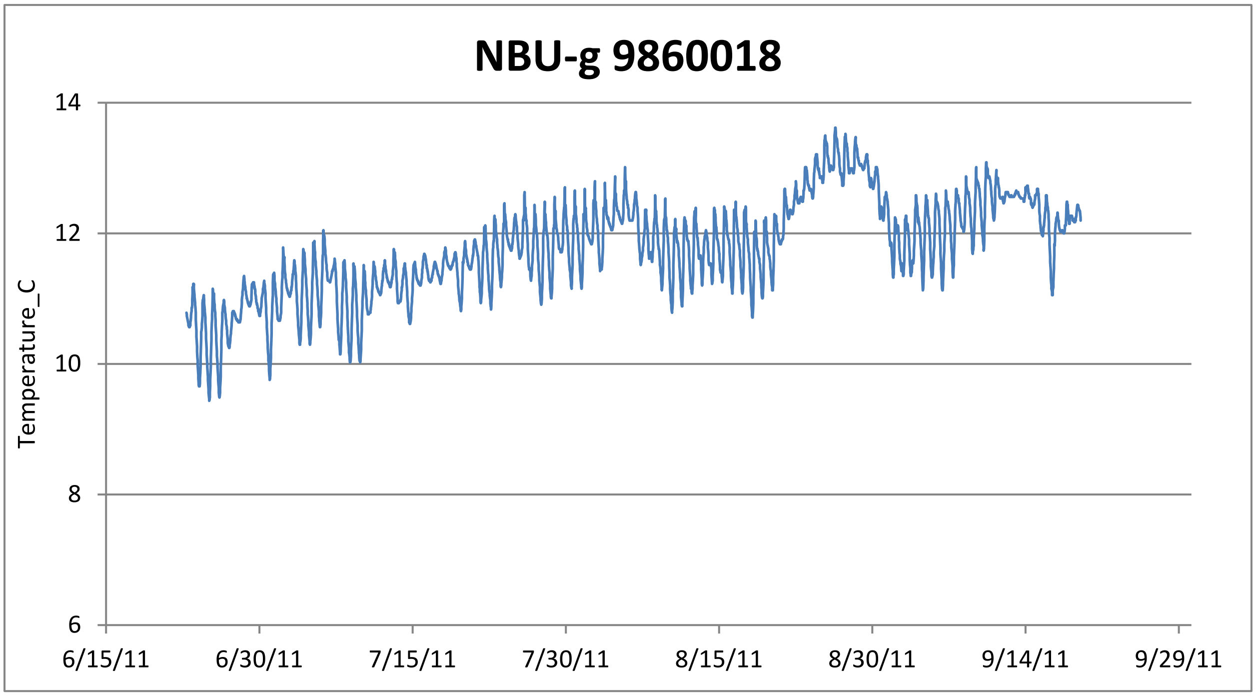

Figure D1. Plot of NBU-g Temperature Data Collected in 2011

Field notes or data showing that the HOBO TidbiT was obviously not in the water were deleted from the data set. Prior to 2009, portions of the streambed in Needle Branch were frequently dry during late summer low flows (see habitat survey maps from mid-August each year). After 2009, flows in Needle Branch were rarely subsurface. In 2015 a significant portion of the main stem Needle Branch was dry, especially in the upper half of the watershed. Field crews checked for dry thermistors approximately every 2 weeks after deployment in June through retrieval in September that year. Less regular visits to check for dry or displaced thermistors were conducted in other years. Flynn and Deer creeks had perennial surface flow every year of the study, and thermistors were rarely found to be dry (displaced). Any data that were obviously from a sensor out of water were archived to a “deleted” table stored on the Oregon State University server. In water years 2006-2011, deleted data represented approximately 4% of the temperature data. Assessments for 2012-2015 are not included in this report.

Table D3 summarizes the deployment history for water years 2006-2011 by the minimum and maximum number of sites and the associated water years, provides the minimum and maximum deleted and their associated water years, provides deployment remarks that characterize site-specific deployment problems, identifies the sites with suspect data, and gives the percentage of suspect data (missing, deleted, or flagged) in the watershed. These data indicate that overall, more than 94% of the data in each watershed are valid, but this varies for each water year and watershed. Assessments for 2012-2015 are not included int this report and were not included in Bladon et al. (2016).

Table D3. Thermistor Temperature Data Quality Assessment 2006-2011

Parameter	Deer Creek	Flynn Creek	Needle Branch
Minimum deployed (WY)	1-2 (2008-2011)	12 (2009)	4 (2007)
Maximum deployed (WY)	16, 10 (2006, 2007)	25 (2011)	26 (2009)
Average deployed (2006-2011)	NA	15	14
Minimum deleted (WY)	0% (2008-2011)	0% (2008, 2009, 2010)	1% (2007)
Maximum deleted (WY)	11.2% (2007)	7% (2011)	9.7% (2006)
Average deleted (2006-2011)	5.6%	2.1%	5.4%
Deployment remarks	Deployment reduced to gauge DC-g (2008-2011) and site DC un_2 (2008, 2011)	None	Different loggers used in 2007 malfunctioned, reducing the number of sites for which data are available
Suspect data sites (2006) (4%)	DC_un2 8/3-9/19 (3.1%)	FC_un2 9/6-9/19 (1.0%)	NB-4 and NB-1 8/31-9/19 NB-6 8/18-9/19 NBU 7/31-9/19 (9.7%)
Suspect data sites (2007) (5%)	DC6_T3 9/11-9/24 DC9_MS 6/1-9/24 (11.2%)	FC_T5 6/1-6/24 FC11_T4 7/9-7/15 (1.3%)	NB2_MS 9/8-9/11 (1.0%)
Suspect data sites (2008) (2%)	None (0%)	None (0%)	NB-3 8/30-9/15 NB-5 7/5-8/17 NB-6 9/13-9/30 (5.6%)
Suspect data sites (2009) (4%)	None (0%)	None (0%)	NB-4 8/7-9/30 NBU-G 7/16-9/7 UNB-A 6/30-8/13 (7.2%)
Suspect data sites (2010) (2%)	None (0%)	None (0%)	NB-1 (replicate) 8/18-8/21 NB-4 (replicate) 7/21-7/30 NB-6 8/6-9/6 (4%)
Suspect data sites (2011) (5%)	None (0%)	FCMS (replicate) 7/3-9/18 (7%)	NB-5 Trib 1 (replicate) 8/30-9/19 NBU-G 9/11-9/14 (3%)

In 2015, diurnal flux (daily max – daily min) was calculated for sites known to be submerged throughout the monitoring period, and the mean ± standard deviation values were compared to data from sites and time periods where drying was questionable.

Conclusions

The overall quality of stream temperature data for the Alsea Watershed Study Revisited is good but incomplete. Most data deleted from the database typically represented water years where a stream site went dry or the thermistor was displaced and out of the water. Table D4 gives an overview of the number of thermistors deployed at each site and the number of values deleted because they were not valid for water years 2006-2011.

Table D4. Overall Data Quality Summary for Thermistor Temperature 2006-2011

	Deer Creek	Flynn Creek	Needle Branch
Minimum deployed (WY)	1-2 (2008-2011)	12 (2009)	4 (2007)
Maximum deployed (WY)	16, 10 (2006, 2007)	25 (2011)	26 (2009)
Average deployed (2006-2011)	NA	15	14
Minimum deleted (WY)	0% (2008-2011)	0% (2008, 2009, 2010)	1% (2007)
Maximum deleted (WY)	11.2% (2007)	7% (2011)	9.7% (2006)
Average deleted (2006-2011)	5.6%	2.1%	5.4%
Deployment remarks	Deployment reduced to gauge DC-g (2008-2011) site DC un_2 (2008 and 2011)	None	HOBO Pro V2 loggers used in 2007 malfunctioned, reducing the number of sites for which data were available
Data quality remarks	Validated	Validated	Validated

REFERENCES

Bladon, K.D., N.A. Cook, J.T. Light, and C. Segura. 2016. "A Catchment-Scale Assessment of Stream Temperature Response to Contemporary Forest Harvesting in the Oregon Coast Range." *Forest Ecology and Management* 379: 153–64.

Bladon, K., N. Cook, J. Light, and C. Segura. 2021. "A Catchment-Scale Assessment of Stream Temperature Response to Contemporary Forest Harvesting in the Oregon Coast Range." Version 1. Oregon State University. https://doi.org/10.7267/ff365c69j.

APPENDIX E

DISSOLVED OXYGEN DATA QUALITY

Synopsis and Data Analysis by George Ice and Terry Bousquet, NCASI
Field Sampling and Data Collection by Cody Hale and David Leer, Oregon State University
Database Management by Amy Simmons, Oregon State University

Introduction

Luminescent dissolved oxygen (LDO) probes and data loggers were deployed to determine dissolved oxygen (DO) concentration, temperature (°C), atmospheric pressure (hPa) and percent DO (%DO) near the Deer Creek (DCG), Flynn Creek (FCG), and Needle Branch gauging stations as part of the Alsea Watershed Study Revisited. Deployment typically occurred from June through October when flows and DO levels were typically at their lowest. This report summarizes the quality of data generated starting in June 2007 and ending September 2015. Calendar dates that probes were deployed at each site are presented in the next section. Data downloaded from data loggers were assessed for unusually low DO or high %DO, null data, and indicators of an instrument malfunction. The results of the data quality assessment are also presented.

LDO Data Logger Deployment

DO determinations were conducted using Hach Model LDO101 probes, and data were recorded using Hach HQd portable meters. Hach's Method 10360, luminescence-based sensor procedure, measures "the light emission characteristics from a luminescence-based reaction that takes place at the sensor-water interface. A light emitting diode (LED) provides incident light required to excite the luminophore substrate. In the presence of dissolved oxygen the reaction is suppressed. The resulting dynamic lifetime of the excited luminophore is evaluated and equated to DO concentration" (Hach 2011).

Measurements were taken at 30-minute time intervals on the dates indicated in Table E1 for each site and year. Data loggers were deployed beginning in June 2007 near Needle Branch upper (NBU), Needle Branch lower (NBL), FCG, and DCG. Deployment at the NB-7 (Needle Branch H-flume [NBH]) gauge site was initiated in July 2008. Deployment at DCG was discontinued after the first year. DO data were collected from May through September 2008 at the first tributary site upstream of FCG (FC-1). Deployment dates were primarily selected to capture lowest flows and hottest days but may have been deployed earlier or later in the year or at additional time intervals depending on temperature, flow conditions, and resource availability. Where deployment occurred on a single date with a limited number of data points, number of hours sampled is reported.

Table E1. LDO Data Logger Deployment

Year	Month	NBL Date Deployed	NBU Date Deployed	NB-7 (NBH) Date Deployed	FCG Date Deployed	DCG Date Deployed	FC-1 Date Deployed
2007	June	6/5-9	6/4-9		6/4-9	6/5-9	
	July	7/2-6	7/2-6		7/2-6	7/2-6	
		7/23-30	7/27-30		7/23-30	7/23-30	
	August	8/3-10	8/3-10		8/3-10	8/3, 8/6-10	
		8/13-17	8/13-17		8/13-17	8/13-17	
		8/20-24	8/20-24		8/20-24	8/20-24	
		8/30-31	8/27-31			8/30-31	
	September	9/1-3				9/1-3	
		9/7-11			9/7-11	9/7-11	
		9/19-23			9/19-23	9/19-22	
		9/26-30			9/26-30		
	October	10/2-6			10/2-3		
		10/11-15	10/11-20		10/11-12		
		10/30-31					
	November	11/1-10	11/1-10				
		11/16-20	11/16-20				
2008	May	5/6-9	5/6-9		5/6-10		5/6-10
	June	6/2-4	6/2-6		6/2-6		
		6/10-13	6/10-14		6/10-13		6/10-14
		6/18-21	6/18-21		6/17-20		6/17-21
		6/27-30	6/27-30		6/24-27		
	July	7/3-7	7/3-7		7/3 (1 hour)		7/3-7
		7/11-15	7/11-15		7/11-15		7/11-15
		7/18-22	7/21-22	7/22-26	7/18-22		7/18-22
		7/24-29	7/27-29		7/26-29		7/27-29
	August	8/1-2	8/1-2				8/1-5
		8/8 (5.5 hours)	8/8-12	8/8	8/8-12		8/8-9
		8/15-19	8/18-25	8/18-21	8/15-19		8/15-19
			8/27-30		8/23-31		8/22-25, 8/27
	September	9/7-8 (10 hours)	9/4 (1 hour)		9/4-8		9/4-8
		9/10-16		9/10-17	9/10-16		9/10-16
		9/18-22			9/18-22		9/18-22
		9/24-30	9/24-30	9/25-30	9/25-30		
	October	10/3-7	10/3-7	10/1 (2 hours), 10/3-7	10/3-7		
			10/10 (2 hours)	10/10 (2 hours)	10/10-12		
					10/18-21		
		10/24-28, 10/31 (11 hours)	10/24-28, 10/31 (12 hours)	10/25-28, 10/31 (10 hours)	10/24-28, 10/31 (3 hours)		

Year	Month	NBL Date Deployed	NBU Date Deployed	NB-7 (NBH) Date Deployed	FCG Date Deployed	DCG Date Deployed	FC-1 Date Deployed
	November	11/1-4	11/1-4	11/1-4			
		11/7-10	11/7-10	11/7-10	11/7-11		
2009	June	6/6-10	6/6-9	6/6-10	6/6-10		
			6/18-21	6/18-22	6/15-18, 6/21		
		6/25-28		6/24-28	6/24-27		
	July	7/9-12	7/10-14		7/10-13		
		7/16-20			7/16-19		
		7/21-26	7/21-26		7/21-24		
		7/27-31	7/27-30	7/27-31	7/27-31		
	August	8/1			8/1-2		
		8/6-12	8/6-9	8/9-8/13	8/6-12		
		8/13-20	8/13-19	8/17-18	8/13-17		
		8/25-29, 8/31 (4 hours)	8/31	8/31			
	September		9/1				
		9/26-28	9/26-28	9/25			
	October		10/1-5	10/1	10/3-5		
		10/8-12	10/8-10	10/8	10/8-9		
		10/15 (2 hours)	10/15 (0.5 hour)	10/16	10/15-19		
		10/23-27	10/23-25		10/23-27		
2010	June	6/17-18	6/22-25	6/22 (7 hours)	6/17 (0.5 hours)		
	July	7/8-9	7/8-10	7/8 (2 hours)	7/8-9		
		7/13-16	7/13-16	7/13 (8 hours)	7/13-16		
		7/26-31	7/26-31	7/26 (7 hours)	7/26-31		
	August	8/1-6	8/1-6	8/2-7	8/2-6		
		8/10-17	8/10-17	8/10-17	8/10-17		
		8/20-25	8/22-28	8/20-26	8/22-25		
	September	9/6 (7 hours)	9/6-10	9/6-10	9/5-9		
		9/17-21	9/17-21	9/17-21			
		9/29-30	9/29-30	9/29-30	9/28-30		
	October	10/1-5	10/1-3	10/1-6	10/1-5		
		10/22-26		10/22-26	10/22-26		
2011	June		6/29-30				
	July	7/1-2	7/1-3		7/1		
		7/6-9	7/6-9	7/6-8 (7/6-7 dup set)	7/6-10		
		7/12-16	7/14-16	7/12-17	7/12-14		
	August	8/5-6	8/5-9	8/5-7	8/5-9		
		8/20-24	8/20-24	8/20-24	8/20-24		
		8/29-31	8/29-31	8/29-31	8/29-31		

E4

Year	Month	NBL Date Deployed	NBU Date Deployed	NB-7 (NBH) Date Deployed	FCG Date Deployed	DCG Date Deployed	FC-1 Date Deployed
	September	9/1	9/1-2	9/1-3	9/1-3		
		9/8-12	9/8-9	9/8-13	9/8-10		
		9/19-23	9/19-23	9/19-24	9/19-23		
			9/30	9/30			
	October		10/1-2	10/1-3			
			10/10-13	10/10-15	10/10 (1.5 hours)		
2012	August	8/1-5		8/1-5	8/1-6		
			8/16-18				
		8/29-31	8/29-31	8/29-31	8/29-31		
	September	9/1-7	9/1-7	9/1-4	9/1-7		
		9/13 (0.5 hours)	9/13 (2.5 hours)	9/13 (0.5 hours)	9/13 (1.5 hours)		
		9/28-30	9/28-30	9/28-30	9/28-30		
	October	10/1-2	10/1-2	10/1-3			
		10/11-14	10/11-15	10/11-14	10/11-14		
		10/17-21	10/17-18	10/17-21	10/18-22		
2013	June	6/19	6/19-24	6/19-20	6/19-20		
		6/25-26	6/26-30	6/26-30	6/25-30		
	July	7/1-6	7/1-4	7/1-7	7/1-7		
		7/15-20	7/15-19	7/15 (0.5 hour)	7/15-20		
		7/31	7/26-31	7/31	7/29-31		
	August	8/1-3	8/1-2	8/1	8/1-3		
		8/13-17	8/9-18	8/13-18	8/13-20		
	September	9/3-7			9/3-7		
2014	June	6/23-28	6/23-28	6/23-28	6/23-28		
	July	7/1-6	7/1-6	7/1-6	7/2-7		
		7/9-14	7/9-14	7/9-14	7/9-14		
		7/21-25	7/21-26	7/21-22	7/21-26		
		7/26-30	7/28-7/31	7/28-30	7/29-31		
	August	8/4-9	8/1-2, 8/6-9		8/1-3		
		8/9-13	8/9-11	8/9-12	8/9		
		8/26-29	8/26-29	8/26 (7.5 hours)	8/26-30		
	September	9/9-13			9/9-13		
2015	June	6/15-19	6/15-19	6/15-20	6/15-19		
		6/29-30	6/29-30	6/29-30	6/29-30		
	July	7/1-4	7/1-3	7/1-4	7/1-5		
		7/8-12	7/8-7/12	7/8-7/13	7/9-14		
		7/27-31	7/27-31	7/27-/31	7/31 (9 hours)		
	August	8/1-3		8/1-6	8/1-5		
		8/9-15	8/8-15	8/8-15	8/13-16		

Year	Month	NBL Date Deployed	NBU Date Deployed	NB-7 (NBH) Date Deployed	FCG Date Deployed	DCG Date Deployed	FC-1 Date Deployed
	September	8/31 (10 hours) 9/1-3 9/18-21		8/31 (12 hours) 9/1-3 9/18-20	8/31 (10 hours) 9/18-21		

Data Validation and Data Flags

The manufacturer's specifications for the Hach Model LDO101 probe are shown in Table E2. The DO measurement range is noted to be between 0.1 and 20 mg/L, with an accuracy of ±0.1 mg/L for values <8 mg/L and ±0.2 mg/L for values >8 mg/L. The minimum sample depth is noted as 0.984 inch or 25 mm.

Table E2. LDO Probe Specifications

LDO Probe Specification Parameter	Specifications
DO range	0.1-20 mg/L, 1-200% saturation
DO accuracy	±0.1 mg/L for 0-8 mg/L ±0.2 mg/L for >8 mg/L
Percent saturation resolution	0.1%
Operating temperature range	0-50°C
Temperature resolution	0.1°C
Temperature accuracy	±0.3°C
Pressure resolution and accuracy	1 hPa, ±0.8%
Minimum sample depth	25 mm (0.984 inch)

The data loggers were factory calibrated by the manufacturer. The manufacturer recommends regular calibration for best measurement accuracy, stipulating that the probe should be calibrated if accuracy better than ±0.5 mg/L is necessary for the application.

Prior to each sampling season, probes were placed in an oxygen-saturated water bath to ensure both the accuracy of DO measurements and consistency of values among probes. Probes were also tested outside the water bath (air calibrated) to provide additional assurance that DO concentrations being measured were consistent among probes and accurately measured a DO saturated condition. In most cases, the factory calibration was found to be within the manufacturer's specifications of ±0.2 mg/L (for DO concentrations >8 mg/L). In a few cases, it was necessary to recalibrate a probe to achieve the desired accuracy. During the study, probes were periodically checked to ensure that the data continued to represent an accurate representation of DO concentrations. This usually involved bringing another laboratory-calibrated (confirmed) LDO probe to the site and checking its values against the field instrument. In addition, to ensure that this relatively new method was not introducing some unknown error, both polarographic DO probe (Yellow Springs Instruments) measurements and modified Winkler titrations were conducted at monitoring sites. This became particularly important when low DO concentrations were observed. Polarographic and Winkler titration DO concentrations were consistent with the LDO probe measurements, although LDO measurements tended to be slightly lower at critical sites. This might reflect a mixing of water elements and atmospheric oxygen during polarographic measurements and collection of water samples for titrations.

Periodically, probe performance was checked by submersing all four probes in a bucket of water that was agitated so DO levels would be near saturation. Example results of the most recent test conducted in March 2014 are shown in Table E3. The difference between minimum and maximum values is within the manufacturer's accuracy specifications for both DO and temperature.

Table E3. Example Probe Performance Check Results

Probe Number	DO Result (mg/L)	Temperature (°C)
1	10.68	9.4
2	10.70	9.5
3	10.76	9.6
4	10.77	9.5
Standard deviation	0.04	0.08
Max-Min	0.09	0.2

The manufacturer stipulates that the probe cap should be replaced every 365 days and generates warning messages when the probe has less than 30 days remaining. The warning is generated based on calendar days from installation and not days of use. Therefore, when the probe was not being used year-round, the warning message may not have reflected performance. During the study, probe caps were to be replaced annually, but over the last few years, we have found that the probes continued to perform well and were not replaced. The same performance checks were conducted as described earlier.

Data collected from data loggers were validated and flagged when there were anomalies that may be of concern to data users. Table E4 lists the data flags used to evaluate DO data prior to incorporation in the database. Data were evaluated for %DO values that were greater than 103%, low DO values, and null values that may have been associated with probe malfunctions or extreme low flow conditions. Data were also evaluated for sudden or erratic temperature spikes that might suggest that the probe was out of the water, unexplained inconsistency, or erratic DO or temperature values that may have suggested fouling of the probe or unusual flow conditions.

Table E4. DO Data Flags

Flag	Criteria	Explanation
High %DO	%DO >103	DO at or near saturation, probe may be out of water
Low DO	DO <1	May be due to probe malfunction or flow conditions
Temperature spike	Sudden spike or erratic temperatures	Sudden spikes or erratic temperatures may mean probe is out of water
Unusual "parameter"	Inconsistent measurements	Unexplained variations may be due to probe malfunction or flow conditions (e.g., unusual temperature, or unusual DO)
Null "parameter"	Null value recorded	Unknown problem, may be due to probe malfunction or dry water conditions

Data validation results using LDO are summarized in Table E5 for each location and year deployed. The number of measurements (n =) taken at 30-minute intervals each year, the minimum and maximum DO, %DO, and temperature values, and the number of values that were outside the data flag criteria or null are presented in the table. The date ranges where DO values were low or null are also included in the table. Dissolved oxygen values were flagged if they were below 1 mg/L or if the value was null.

Null values may be associated with an instrument malfunction or may represent times when DO was below detectable levels. Null value counts in each water year are in parentheses in the DO column of Table E5. Data were also flagged if %DO was greater than 103% or if hPa values were null. In the few instances with elevated temperatures (>18°C), the probe may have been out of the water where the temperature reflects air temperature. In these instances, the data should be evaluated against temperature measurements collected using the turbidity threshold sampling system.

Table E5. DO Data Quality Summary

		DO				%DO			hPa	Temperature	
Site/ Year	n =	n = <1 (null)	Min mg/L	Max mg/L	Dates Low or Null	n = >103 %	Min %	Max %	n = Null	Min °C	Max °C
NB-7 (NBH)											
2008	1,690	125 (157)	0.02	11.00	8/18 (0.5 hour), 9/10-16, 11/7-10	0	0.2	100.7	1	8.5	12.9
2009	1,061	17 (208)	0.04	10.57	6/21-22, 6/24-28	0	0.4	102.4	34	9.6	16.5
2010	1,861	0	3.96	11.22		3	37.6	104.1	0	9.2	14.4
2011	1,803	0	9.05	11.01		0	87.4	102.8	0	9.4	13.5
2012	989	84	0.01	10.46	8/3-5, 9/29, 10/13-14, 10/19	0	0.1	96.5	0	8.1	14.6
2013	817	0	1.23	10.19		0	11.8	94.1	0	10.4	12.9
2014	957	17	0.15	10.40	7/4-5, 8/26	0	1.5	98.8	0	10.5	16.2
2015	1,814	0	3.40	10.16		0	33.0	90.5	0	8.9	13.3
Overall	1,0992	243 (365)	0.01	11.22		3	0.1	104.1	35	8.1	16.5
NBU											
2007	2,275	0	2.07	12.49		285	19.6	110.7	0	8.6	18.8
2008	3,041	0	2.59	11.65		0	24.1	102.5	0	7.1	12.9
2009	1,876	0	1.81	10.30		0	17.6	95.8	0	10.2	14.0
2010	2,128	0	3.99	9.96		0	38.5	93.5	0	10.5	13.4
2011	1,573	101 (3)	0.00	10.34	8/23 (3), 8/29-8/31, 9/1-9/2, 9/22-9/23	0	0.0	98.4	0	10.3	12.6
2012	909	7	0.49	10.77	9/29 (1), 10/2 (4), 10/11(2)	0	4.5	96.4	0	9.7	14.4
2013	1,456	0	7.40	9.83		0	70.9	89.0	0	9.9	13.3
2014	1,603	0	3.05	9.78		0	29.1	92.3	0	10.6	13.4
2015	1,174	1	0.79	9.42		0	7.5	86.0	0	9.9	15.3
Overall	1,6035	109 (3)	0.00	12.49		285	0.0	110.7	0	7.1	18.8
NBL											
2007	3,145	35 (122)	0.06	11.06	9/3 (2), 10/11-12, 11/1, 11/16-19	0	0.5	94.8	0	6.2	13.8
2008	3,266	0	5.79	11.43		15	53.8	104.6	0	6.2	15.5
2009	2,457	0	1.01	10.50		0	9.9	92.7	0	7.0	15.2
2010	2,017	0	5.71	10.76		0	56.0	97.2	0	9.0	14.0
2011	1,273	0	4.56	10.04		0	44.1	90.6	0	9.6	14.7

		DO				%DO			hPa	Temperature	
Site/ Year	n =	n = <1 (null)	Min mg/L	Max mg/L	Dates Low or Null	n = >103 %	Min %	Max %	n = Null	Min °C	Max °C
2012	1,073	0	5.57	10.65		0	52.3	93.9	0	8.3	14.4
2013	1,101	0	5.76	9.70		0	56.8	89.6	0	10.5	14.6
2014	1,805	1 (300)	0.06	9.51	8/4-9, 8/10-12	0	0.6	90.6	0	10.7	15.2
2015	1,531	1	0.8	9.38		0	7.8	86.4	0	10.2	15.3
Overall	1,7655	37 (422)	0.06	11.43		15	0.5	104.6	0	6.2	15.5
FCG											
2007	2,055	0	9.07	11.12		0	86.0	102.6	0	8.7	15.6
2008	3,720	0	8.82	12.00		221	81.6	112.5	0	6.2	17.0
2009	2,227	0 (1)	5.95	11.07	8/8 (1)	9	60.0	117.5	0	7.2	16.7
2010	1,789	0 (3)	9.08	11.49	7/8, 7/9, 7/14	8	85.2	107.8	0	8.7	14.4
2011	1,180	0	8.70	10.69		0	83.9	97.7	0	9.4	14.5
2012	1,033	0	4.42	11.17		0	40.2	97.6	0	7.4	14.7
2013	1,500	2	0.56	10.87	9/5 (2)	0	5.4	102.6	0	9.4	21.8
2014	1,519	0	9.05	10.09		0	89.5	95.7	0	11.1	15.4
2015	1,226	(5)	2.66	17.30	7/1 (1), 7/2 (2),7/3 (1), 7/4 (1)	308	25.8	164.6	0	9.5	16.6
Overall	1,6249	2 (9)	0.56	17.30		546	5.4	164.6	0	6.2	21.8
FC-1											
2008	2,464	28	0.05	11.91	8/15-18	0	0.5	102.5	0	6.0	14.6
DCG											
2007	1,743	0	8.20	11.25		3	80.5	103.4	0	9.4	15.9

Low or null DO values occurred most frequently at the farthest upstream Needle Branch site (NB-7/NBH) with 608 (6.6%) low or null values, most of which were in preharvest years (282 in 2008 and 225 in 2009). A large number of null values were also observed at NBL in 2014; this appeared to be due to the probe being covered by silt. Segments flagged for low or null values should be compared with discharge data to determine whether this was the result of low or no flow conditions.

As expected, where DO values were null, %DO was null. However, there were a few episodes when DO was measured but %DO could not be calculated because the atmospheric pressure measurement (hPa) was outside of range indicating an instrument malfunction. All 35 of the %DO null values associated with hPa errors were from the NB-7 (NBH) site. Percent DO values greater than 103% were flagged as "high %DO" in the database. This occurred most frequently at the NBU site in 2007 (n = 285) and the FCG site in 2008 (n = 221).

The minimum and maximum temperature values are also presented in Table E5. In some instances, it appeared that high temperature values might be due to the probe being out of the water. These data should be evaluated on a case-by-case basis against field notes or other in-stream temperature data.

Conclusions

Overall, the data show a high level of data quality with more than 94% of values at each site meeting the criteria of valid data. The highest rate of data flags was observed at the NB-7 location due to a high number of low or null DO values, which would be expected in upper stream reach where stretches often go dry in summer months. Overall data quality parameters are summarized in Table E6. For instrument-collected DO data, this represents a low level of censuring (see, e.g., DaSilva et al. 2013).

Table E6. Overall Data Quality Summary for DO

Site Location	n =	DO <1 mg/L or Null	DO% >103%	Temperature (°C)
NB-7 (NBH)	10,992	608 (5.5%)	3 (<0.1%)	8.1-16.5
NBU	16,035	112 (0.7%)	285 (1.8%)	7.1-18.8
NBL	17,655	459 (2.6%)	15 (0.1%)	6.2-15.5
FCG	15,557	6 (<0.1%)	238 (1.5%)	6.2-21.8
FC-1 (2008)	2,464	28 (1.1%)	0	6.0-14.6
DCG (2007)	1,743	0	3 (0.2%)	9.4-15.9

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APPENDIX F

ALSEA NUTRIENT DATA SAMPLING AND ANALYSIS QUALITY ASSURANCE/QUALITY CONTROL SUMMARY

Quality Assurance/Quality Control Evaluation and Synopsis Prepared by Terry Bousquet, NCASI
Field Sampling Conducted by Cody Hale and David Leer, Oregon State University

Laboratory Analysis and Data Review Conducted by Diana Cook, Jan Napack, and David Campbell, NCASI

Introduction

Grab samples were collected at gauging stations and synoptic sites located throughout Deer Creek (DCG), Flynn Creek (FCG), and Needle Branch for nutrient analyses as part of the Alsea Watershed Study Revisited. Nutrient sampling and analytical data generated from October 2005 through September 2014 were evaluated against the performance criteria in the Alsea Watershed Study Revisited quality assurance project plan and are summarized herein. This appendix describes sample collection frequency and analysis schedules for each nutrient parameter and assesses data for missing or incomplete data collection. Nutrient sampling information is further assessed to determine the frequency and locations where samples were not collected because the stream segment was dry and to characterize field sampling precision. And, analytical quality assurance and quality control (QA/QC) performance is characterized for each nutrient parameter.

Sample Collection and Analysis Schedule

Beginning in October 2005, grab samples were collected monthly at the DCG, FCG, lower Needle Branch (NBL), and upper Needle Branch (NBU) gauging stations. They were analyzed for nitrate-nitrite, ammonia, orthophosphate (OP), total phosphorus (TP), and total nitrogen (TN) or total Kjeldahl nitrogen (TKN). Beginning in November 2006, samples were also collected monthly at an additional Needle Branch synoptic site (NB-7) for the same list of nutrient parameters. In November 2007, an H-flume and gauge were installed at that site (NB-7 = NBH-G).

Additional monthly grab samples were collected at synoptic sites at 6 locations in Needle Branch, 12 locations in DCG, and 12 locations in FCG beginning in November 2005. They were analyzed for ammonia and nitrate-nitrite. Three synoptic sites on Needle Branch were added in November 2007 (UNB-A, UNB-B, and UNB-C). Ammonia analyses were discontinued at all synoptic sites in October 2010 because the results were consistently at or below the method detection limit and because of workload limitations in NCASI's laboratory and the field. As of October 2010, sampling for nitrate-nitrite at most FCG and Needle Branch synoptic sites was reduced to quarterly; NB-5, UNB-A, UNB-B, UNB-C, FC-1, and FC-2 continued to be collected monthly. Synoptic sampling at DCG was discontinued in February 2010 because the sites were too difficult to access and field staff availability was limited. All synoptic sampling was discontinued in October 2014. Also beginning in 2014, TP analyses were only conducted if OP results were >0.04 mg/L. This cutoff value was determined based on the 75th percentile values in the control streams.

Sampling scheduled for February 2011 was postponed, and a limited sample set was collected on March 7 due to limited field staff availability. The regular sampling for March was conducted on March 27, 2011.

The nutrient analysis sampling frequency schedule is presented in Table F1 for each gauge and synoptic site. Months when samples were not collected due to inaccessibility during harvest or field sampler availability are shown as missing data. These sites would be noted as not sampled (NS) in the database. Missing data were compared to the overall expected frequency of sample collection to determine percent completion (%complete). Missing data and %complete values do not reflect cases when samples were not collected because a site was dry. When there was no water in a stream, the sample inventory record is flagged as “NRNW” (not received, no water). An assessment of the frequency and location of NRNW flagged data is presented in the next section. When a sample was not collected for other reasons, it was flagged as NS. This missing data summary is complete through March 2016.

Table F1. Nutrient Sampling and Analysis Schedule with %Completion Rate

Sample Location	Sample Description	Nutrient Analyses	Frequency	Missing Data	%Complete
NBL	NB weir lower gauge	OP TP TN or TKN[a] Nitrate-nitrite Ammonia	Monthly October 2005-March 2016	November 2008 November 2010	98%
NBU	NB weir upper gauge	OP TP TN or TKN Nitrate-nitrite Ammonia	Monthly October 2005- March 2016	November 2008 November 2010 February 2011 September 2014	97%
NB-7 (NBH)	NB synoptic site 7 and H gauge	OP TP TN or TKN Nitrate-nitrite Ammonia	Monthly November 2006-March 2016	November 2008 July 2009 November 2010 February 2011	97%
FCG DCG	FC and DC-G weirs	OP TP TN or TKN Nitrate-nitrite Ammonia	Monthly October 2005-March 2016	November 2008 November 2010	98%
All Synoptic Sampling Was Discontinued in October 2014					
NB-1	NB synoptic site 1	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	May, October, November 2008	95%
NB-1	NB synoptic site 1	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	May, October, November 2008	96%
NB-2 NB-3 NB-4	NB synoptic sites 2-4	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	May, October, November 2008	95%
NB-2 NB-3 NB-4	NB synoptic sites 2-4	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	May, October, November 2008 December 2010, September 2014	95%
NB-5	NB synoptic site 5	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	November 2008	98%
NB-5	NB synoptic site 5	Nitrate-nitrite	Monthly November 2005-September 2014	November 2008 November 2010 February 2011 September 2014	97%

Sample Location	Sample Description	Nutrient Analyses	Frequency	Missing Data	%Complete
NB-6	NB synoptic site 6	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	May, October, November 2008 July 2009	93%
NB-6	NB synoptic site 6	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	May, October, November 2008 July 2009 September 2014	97%
UNB-A UNB-B	Upper NB synoptic sites A, B	Ammonia	Monthly October 2007-September 2010; discontinued October 2010	November 2008 July 2009	97%
UNB-A UNB-B	Upper NB synoptic sites A, B	Nitrate-nitrite	Monthly October 2007-September 2014	November 2008 July 2009 November 2010 February 2011	97%
UNB-C	Upper NB synoptic site C	Ammonia	Monthly October 2007-September 2010; discontinued October 2010	October-November 2008 July 2009	95%
UNB-C	Upper NB synoptic site C	Nitrate-nitrite	Monthly October 2007-September 2014	October-November 2008 July 2009 November 2010 February 2011	96%
FC-1	FC synoptic site 1	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	November 2008	98%
FC-1	FC synoptic site 1	Nitrate-nitrite	Monthly November 2005-September 2014	November 2008 October-December 2010 January 2012 January 2013	95%
FC-2	FC synoptic site 2	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	October-November 2008	97%
FC-2	FC synoptic site 2	Nitrate-nitrite	Monthly November 2005-September 2014	October-November 2008 October-December 2010 February 2011 January-February 2012 January 2013	92%

Sample Location	Sample Description	Nutrient Analyses	Frequency	Missing Data	%Complete
FC-3 FC-4	FC synoptic sites 3, 4	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	October-November 2008 June 2010	95%
FC-3 FC-4	FC synoptic sites 3, 4	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	October-November 2008 June, December 2010	95%
FC-5	FC synoptic site 5	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	October-November 2008 October 2009 June 2010	93%
FC-5	FC synoptic site 5	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	October-November 2008 October 2009 June, December 2010	94%
FC-6	FC synoptic site 6	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	October-December 2008 November 2009 April, June, September 2010	91%
FC-6	FC synoptic site 6	Nitrate-nitrite	Monthly November 2005-September 2010; quarterly October 2010-September 2014	October-December 2008 November 2009 April, June, September 2010	92%
FC-7 FC-8 FC-9 FC-10 FC-11 FC-12	FC synoptic sites 7-12	Ammonia	Monthly November 2005-September 2010; discontinued October 2010	May, October-December 2008 November 2009 April, June, September 2010	88%
FC-7 FC-8 FC-9 FC-10 FC-11 FC-12	FC synoptic sites 7-12	Nitrate-nitrite	Monthly November 2005-December 2010; quarterly January 2011-September 2014	May, October-December 2008 November 2009 April, June, September, December 2010	89%

Sample Location	Sample Description	Nutrient Analyses	Frequency	Missing Data	%Complete
DC-1 DC-1A DC-2 DC-3 DC-4 DC-5 DC-6 DC-7 DC-8 DC-9 DC-10 DC-11	DC synoptic sites 1-11, 1A	Ammonia Nitrate-nitrite	Monthly November 2005-January 2010; discontinued February 2010	May, October-November 2008 January, June, September-December 2009	82%

[a] TN beginning January 2010; TKN discontinued April 2010.

Nutrient Field Sampling

Field Sampling Flags

Each sample was assigned a laboratory code and entered into the Nutrient Sample Inventory Table of the Alsea Database. If the field sampler made a notation during sampling that identified a quality assurance sample or a problem with sampling, a qualifier was included in the inventory table as shown in Table F2. Sampling qualifiers were identified for low water where there may have been high amounts of sediment (LWSED), NS, or not received because there was no water (NRNW). Sites with missing data reported previously in Table F1 were flagged in the database as NS. An assessment of the frequency and location of dry segments is presented in the next section. A field duplicate was collected at one gauging station each quarter to evaluate field sampling precision, which was characterized for each of the nutrient parameters in the section titled “Field Sampling Precision.” Additional replicates have not been collected to date.

Table F2. Nutrient Sampling Flags

Code	Definition
FD	Field duplicate
FR1	Field replicate 1
FR2	Field replicate 2
FR3	Field replicate 3
FR4	Field replicate 4
LWSED	Low water sediment
NS	Not sampled
SA	Sample
NRNW	Not received, no water

Dry Segment Flags

Table F3 shows sample collection dates and sample sites where samples were not collected because there was no water at the sampling location. Forty sites were dry in Needle Branch, 14 in DCG, and 15 in FCG. All dry sites were tributary sites except the NBU gauging station, which was noted as dry once in

September 2007 and once in August 2015. The sites most frequently dry were UNB-C (20) and NB-3 (8) in Needle Branch, DC-8 (7) in DCG, and FC-7 (12) in FCG. Sample collection was initiated at the UNB-C site in October 2007, and that site was dry from July through September in most water years. Sampling at all tributary sites was discontinued in September 2014.

Table F3. Nutrient Samples Flagged NRNW

Sampling Date	Needle Branch	DCG	FCG
2005	None	none	none
8/14/2006	NB-3		FC-7
9/25/2006	NB-3	DC-3, DC-8	FC-7
10/30/2006	NB-3	DC-3, DC-8	FC-7
8/6/2007		DC-8	FC-7
9/17/2007	NB-3, NBU	DC-3, DC-8	FC-7
10/29/2007		DC-8	
7/21/2008	UNB-C		
8/18/2008	UNB-C		
6/01/2009	UNB-C		
7/20/2009	UNB-A, UNB-B, UNB-C	DC-1A, DC-3, DC-8	
8/17/2009	NB-3, NB-5, UNB-C	DC-1A, DC-3, DC-8	FC-7
9/21/2009	NB-3, NB-5, UNB-B, UNB-C		FC-3, FC-5, FC-7
7/12/2010	UNB-C		
8/30/2010	UNB-C		FC-7
9/27/2010	NB-3, UNB-A, UNB-B, UNB-C		
8/28/2011	UNB-C		
9/19/2011	NB-3, UNB-A, UNB-B, UNB-C		FC-3, FC-7
7/23/2012	UNB-C		
8/20/2012	UNB-C		
9/3/2012	UNB-C		FC-7
7/15/2013	UNB-C		
8/19/2013	UNB-C		
9/09/2013	UNB-C		FC-7
6/23/2014	UNB-C		
7/21/2014	UNB-C		
8/26/2014	UNB-C		
9/29/2014	UNB-C		FC-7
8/31/2015	NBU		

Field Sampling Precision

Duplicate grab samples were collected quarterly at different gauging stations to evaluate field sampling precision. The location rotated each quarter between the NBL, NBU, FCG, and DCG gauges to ensure that data quality was representative of all three watersheds. Both field duplicate results are included in a nutrient results table in the Alsea database. Field duplicate measurements reflect both field sampling and laboratory variability, which include any sample preparation (digestions) and instrument variability. Therefore, field duplicates are expected to be more variable than laboratory duplicates. Laboratory precision is discussed later. Field duplicates that did not meet a precision criterion of <35% relative percent different (RPD) were flagged as failed field precision (FFP) with the RPD in brackets (e.g., FFP[40%]) in the nutrient results table. Field sampling precision is summarized in Table F4 for nitrate-nitrite, total nitrogen using persulfate digestion (TNP), OP, total phosphorus using persulfate digestion (TPP), and a limited number of measurements for TKN.

Table F4. Field Duplicate Precision

Nutrient Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average ± 2 Std Dev
Nitrate-nitrite %RPD	41	1.02	2.40	0.00	14.6	5.8
TKN %RPD[a]	4/17	16.8	12.3	3.6	27.6	41.4
TNP %RPD	26	4.51	6.09	0.00	22.7	16.7
OP %RPD	41	3.42	4.41	0.00	14.3	12.2
TPP %RPD	33	13.8	18.1	0.00	80.0[b]	50.0
	29	8.43	9.33	0.00	33.9[c]	27.1

[a] Field duplicate RPD calculated if blank subtracted result >0.05 mg/L.
[b] Four RPDs exceeded 35%.
[c] Result removed when value >35%.

Ammonia field duplicate measurements were below the quantitation limit or equivalent to method blank levels. Therefore, it was not possible to characterize field precision for ammonia. Nitrate-nitrite, TN, and OP RPDs were within expected limits. TP RPDs exceeded the limit four times out of 33 field measurements. The table shows the statistics with and without these measurements. Four of 17 TKN field duplicate results were greater than the reporting limit of 0.5 mg/L and sufficiently above the method blank to determine precision. None of the four TKN RPDs exceeded the 35% RPD maximum criterion, but highly variable blank levels contributed to overall variability. Although the data quality plan established an initial precision criterion of 35%, the average plus or minus two times the standard deviation is a measure of actual field and laboratory precision. Nitrate-nitrite, TN, and OP showed field duplicate precision measurements of 6.3, 18.7, and 13.3%, respectively. Precision for these parameters reflects field and instrument performance. Precision for TN and total phosphate include field, digestion, and instrument variability and would be expected to have greater variability due to the digestion step, as was evident in the data presented in Table F4.

Nutrient Analytical QA/QC

Nutrient analyses were initially conducted using an Alpkem flow analyzer, which was replaced in June 2007 with a Bran+Luebbe flow analyzer. All samples were analyzed within accepted holding times. Where sample analyses failed to meet QA/QC criteria, the data were flagged in the database to assist researchers when interpreting results. The flags used in the nutrient results table of the database are described next. QA/QC data are summarized in the following sections for each nutrient parameter.

Nutrient QA/QC Flags

Analytical method blanks, calibration check samples, laboratory duplicates, and matrix spikes (MS) were conducted with each analytical batch for each nutrient parameter. Laboratory duplicate and MS samples were selected from a different site each month to ensure that each watershed was represented. The quality assurance project plan indicates that laboratory duplicate and matrix spike duplicate (MSD) precision must meet a criterion of <25% RPD. Recoveries for MS must be between 70 and 130%. Data associated with failed QA/QC parameters may have been flagged as shown in Table F5.

Table F5. Nutrient Results QA/QC Flags

Data Flag	Description
<LCL	Value estimated below lower calibration limit
B1	Less than level in method blank
B2	Less than two times level in blank
B3	Less than three times level in blank
B5	Less than five times level in blank
E	Reported value estimated because of interference
FCCV[x]	Failed calibration check verification [%recovery]
FFP[x]	Failed field precision [%RPD]
FLP[x]	Failed laboratory precision [%RPD]
FMS[x]	Failed matrix spiked recovery
FQA	Outside laboratory quality control limits
HZ	Hyporheic zone
INT	Matrix interference
ISL	Insufficient spike level
NA	Not analyzed
ND	Not detected above method quantification limit
NS	Not sampled
NW	No water

Nutrient sample results include a numeric result and a reported result. Where a numeric result is less than the quantitation limit, the concentration is not within the linear range of the instrumentation, and the reported value is shown as ND. The quantitation limit is based on method blank background levels, limits of detection based on instrument performance, and calibration range. The numeric result is provided to allow principal investigators to evaluate importance and reliability of a result when analyzing the data, preparing data plots, or conducting statistical analyses. The data are flagged as ND[x] with the quantitation limit provided [x].

Analytical method blanks vary from batch to batch depending on the nutrient parameter measured, potential contamination of glassware, reagents, and instrument background levels. Where the analytical result is more than five times the method blank level, the background has little effect on results, such as nitrate-nitrite levels. Where the analytical result is at or near the method detection limit, such as with ammonia data, contributions from method blanks can significantly affect results. When this occurred, data were flagged depending on the level in the blank relative to the level in the sample (e.g., ≤2 times the blank level = B2).

Independent calibration verification (ICV), continuing calibration verification (CCV), laboratory duplicates, MS, and MSD were conducted with each analytical batch for each nutrient parameter. Where a digestion step was part of sample preparation for analysis, the ICV and CCV represent instrument performance, and the digested independent calibration verification (dICV) and digested continuing calibration verification (dCCV) represent data quality across the entire analytical process. An ICV is a standard purchased from an independent source, and a CCV is an aliquot of a standard used for calibration. MSs are spikes of a known amount of the nutrient in a sample aliquot. When native duplicate sample results are at nondetect levels, the RPD of MSDs are used to assess precision in the sample matrix. Quality control data are summarized for each nutrient parameter in the following sections.

Nitrate-Nitrite QA/QC Summary

Nitrate-nitrite QA/QC results are summarized in Table F6 for Alsea samples collected from September 2005 through March 2016. All QA/QC parameters met the QA/QC criteria, and no data were flagged.

Table F6. Nitrate-Nitrite Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Analytical blank mg/L	124	0.01	0.005	0.00	0.02		0.02
ICV %Recovery	245	98.2	2.55	82.1	106	93.1	103
CCV %Recovery	241	97.4	2.46	84.2	108	92.5	102
Sample duplicate %RPD	120	0.59	1.41	0.00	15.0		3.41
MS/MSD %Recovery	241	99.5	5.31	84.2	123	88.8	110
MS/MSD %RPD	119	1.22	1.81	0.00	11.5		4.8

Figure F1 shows nitrate-nitrite MS recovery data. Dotted lines represent plus and minus two times the standard deviation, and solid lines represent the minimum and maximum acceptance criteria of 70-130%. As shown in the figure, all data were within the acceptance criteria. Most recoveries that were outside the average plus or minus two standard deviations (88.1 to 110%) were conducted using an Alpkem flow analyzer that was replaced with a Bran+Luebbe flow analyzer in June 2007.

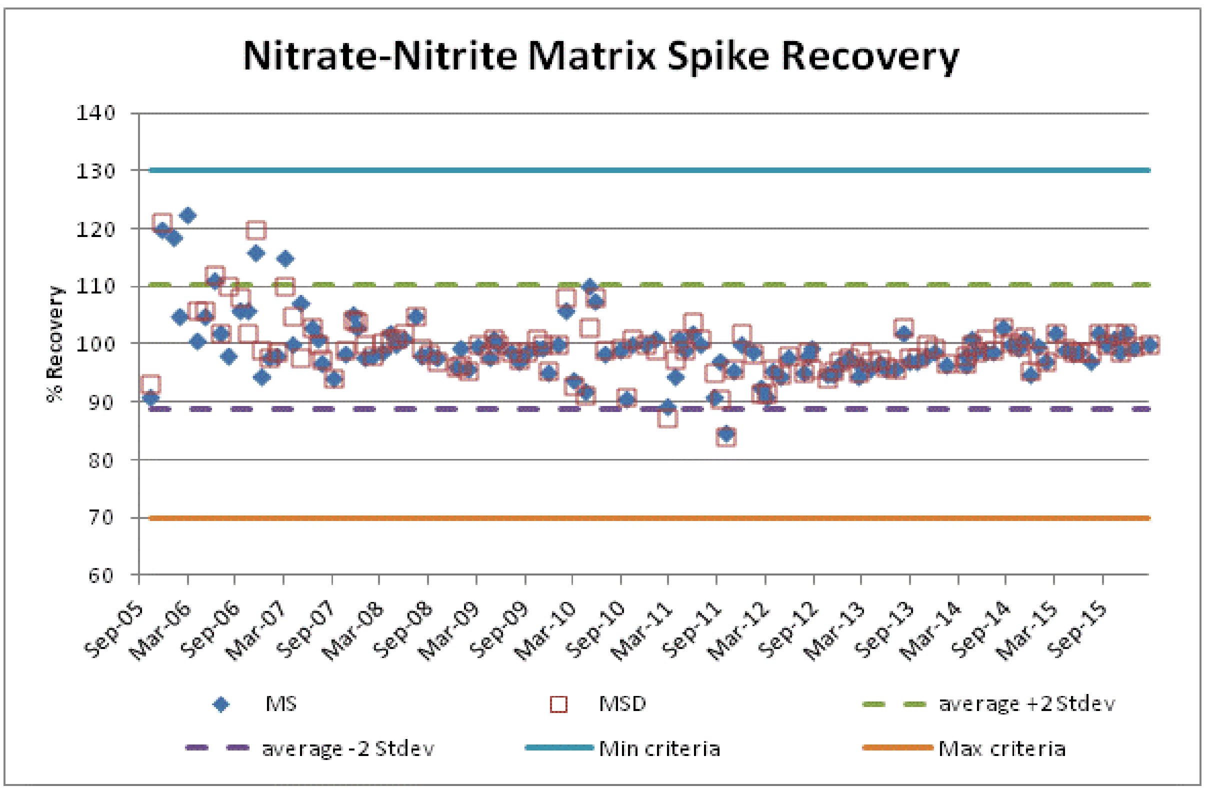

Figure F1. Percent Recovery of Nitrate-Nitrite MSs and MSDs

Ammonia QA/QC Summary

Ammonia QA/QC data are summarized in Table F7 for measurements conducted through August 2014 when these analyses were discontinued due to the high number of values at or near method blank levels. Both ICV and CCV results were within acceptable limits. Most samples had concentrations that were nondetect or less than or equal to two times method blank levels. Therefore, a determination of analytical precision based on laboratory duplicates was not valid. Precision was characterized by the RPD of MS and MSD data. The maximum RPD of MSDs was 16%. Only one MS measurement at 164% was outside the 70-130% MS acceptance criteria. It was conducted using the Alpkem analyzer.

Table F7. Ammonia Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Analytical blank mg/L	105	0.01	0.006	0.00	0.02		0.02
ICV %Recovery	208	99.6	5.2	81.7	117	89.2	110
CCV %Recovery	203	97.5	3.9	83.6	112	89.7	105
MS/MSD %Recovery	206	104	7.6	92.7	164	89.3	120
MS/MSD %RPD	101	1.16	2.09	0.0	16		5.4

To illustrate the effect of method blank levels on sample measurements, method blank, field duplicate, and analytical duplicate data were plotted in Figure F2. The solid line represents the average method blank plus two times the standard deviation. Most results were below this level, indicating that there is not a statistically significant difference between method blanks and sample concentrations. Therefore, continued collection of data for ammonia had very limited value when being used to compare paired watersheds or results before and after harvest. Therefore, these analyses were discontinued in September 2014.

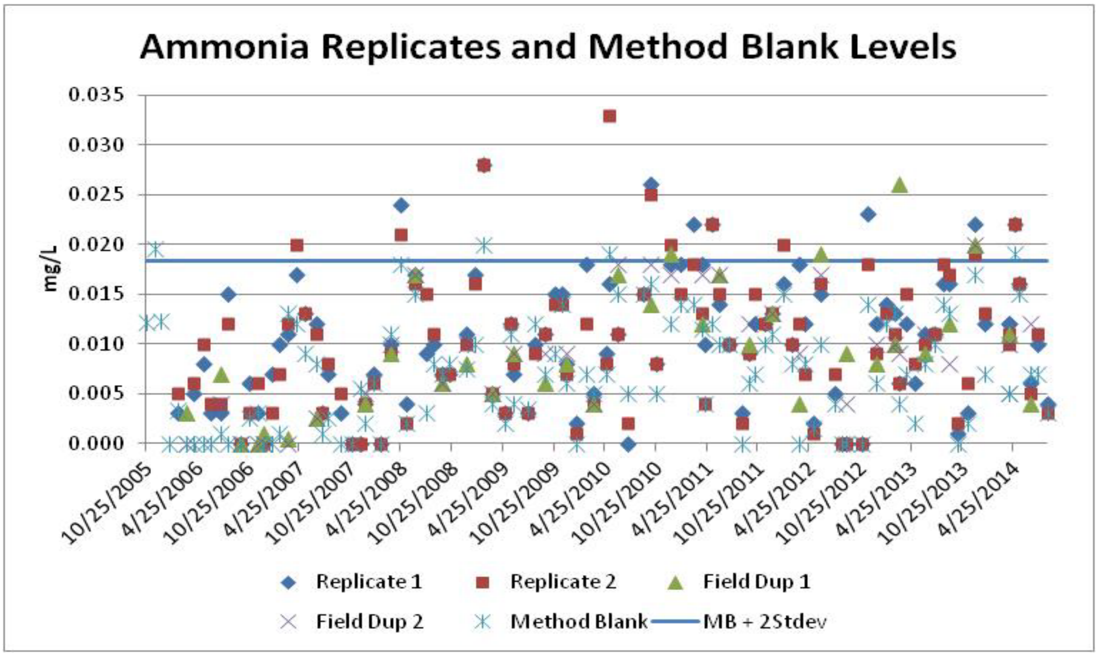

Figure F2. Ammonia Replicate Analyses and Method Blank Levels

Recoveries of ammonia MSs and MSDs are shown in Figure F3. As noted, only one MS exceeded the acceptance criteria of 70-130%. Overall recoveries were higher when the Alpkem data system was being used prior to June 2007, which is when the maximum acceptance criterion was exceeded. Data that exceeded the acceptance criterion were flagged in the nutrient results data table.

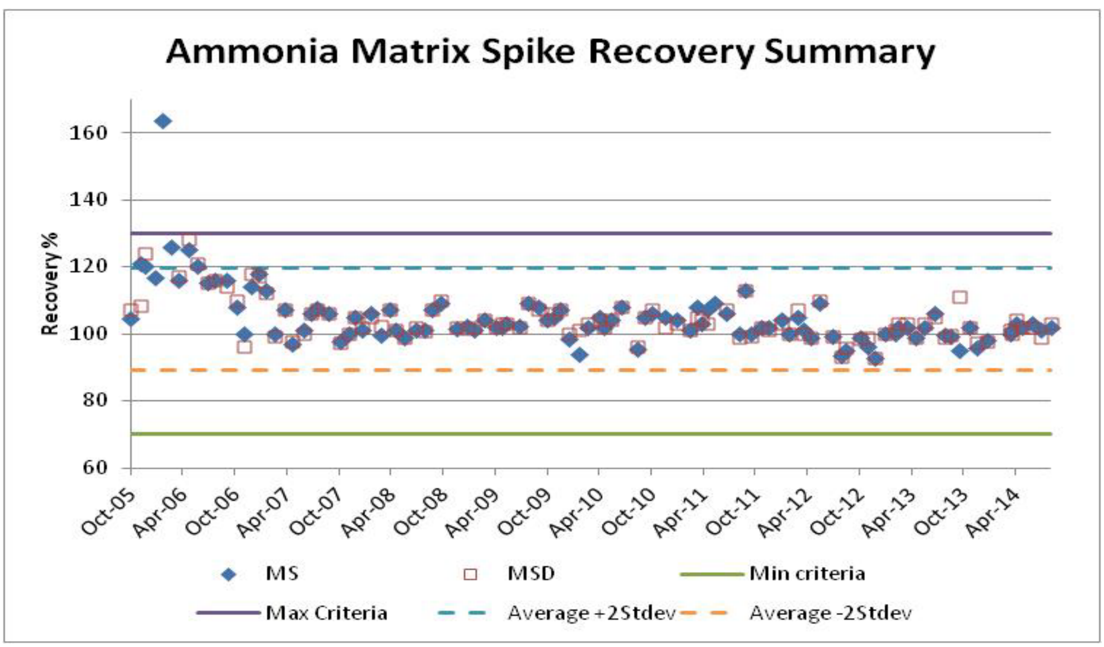

Figure F3. Ammonia Matrix Spike Recovery Data

TN QA/QC Summary

TN was historically measured as TKN, a measure of organic nitrogen and ammonia using a Kjeldahl digestion procedure. TN measures nitrate-nitrite, organic nitrogen, and ammonia using an alkaline persulfate digestion procedure. Therefore, TN minus nitrate-nitrite is equivalent to TKN. As noted in the previous section, the contribution of ammonia to TN or TKN is negligible because values were near quantification limits and blank levels. The TKN procedure was used at the start of this study in October 2005, but these measurements were discontinued in April 2010 because high digestion reagent background levels interfered with the low-level concentrations in the samples. In January 2010, analyses were initiated to measure TN using an alkaline persulfate procedure (TNP), providing 4 months of overlapping data. This change was made because TKN digestion blank problems raised quantitation limits such that data were unreliable and because US Geological Survey and other agencies had discontinued using TKN and were using the alkaline persulfate procedure.

Digestion blanks take into consideration the entire analytical process from sample digestion and preparation through analysis. Digestion method blank levels were subtracted from digested sample measurements from the same analytical batches to quantify TKN concentrations. At the beginning of the study, TKN measurements were performed using a copper sulfate digestion solution. In June 2007, mercuric sulfate was used for digestion to achieve lower and more consistent method blank levels compared with the copper sulfate method blanks. Regardless of the digestion reagent used, most sample measurements were at or near the levels in the method blanks.

Data for TKN QA/QC showing method blank levels and quality control check results for both the copper sulfate and mercury digestion reagents are reported in Table F8. Analyses of ICVs and CCVs were conducted with and without digestion. Undigested ICV and CCV results represented instrument performance, and digested dICV and dCCV results represented overall analytical performance more closely mimicking sample performance. A high number of dICV (7 of 49), dCCV (20 of 75), and MS (21 of 107) analyses were outside the performance limits of 70-130%, further indicating unreliable performance for the TKN method.

Table F8. TKN Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Digestion blank TKN-Cu mg/L	20	0.42	0.30	0.05	1.05		1.01
Digestion blank TKN-Hg mg/L	35	0.11	0.08	0.00	0.34		0.26
ICV TKN-Cu %Rec	35	103	6.31	86.0	120	89.9	115
ICV TKN-Hg %Rec	70	99.6	4.74	89.5	113	90.1	109
CCV TKN-Cu %Rec	37	98.4	5.92	84.0	114	86.5	110
CCV TKN-Hg %Rec	70	99.3	4.26	82.8	113	90.9	108
dICV TKN-Cu %Rec	14	105	14.2	85.0	138	76.7	134
dICV TKN-Hg %Rec	35	81.7	17.2	61.0	151	47.7	116
dCCV TKN-Cu %Rec	14	106	14.5	85.4[a]	135	77.0	135
dCCV TKN-Hg %Rec	61	78.1	13.1	55.9	123	52.0	104
Sample RPD TKN-Cu %Rec	19	10.2	8.66	0.00	28.1		27.5
Sample RPD TKN-Hg %Rec	31	16.0	11.6	1.7	46.7		39.1
MS/MSD TKN-Cu %Rec	39	101	20.0	64.6	133	61.2	141
MS/MSD TKN-Hg %Rec	68	84.0	17.7	45.6	148	48.6	119
MS/MSD TKN-Cu %RPD	19	3.59	5.07	0.00	20.8		13.7
MS/MSD TKN-Hg %RPD	34	9.8	9.7	0.00	47.7		19.3

[a] One outlier at 29% removed.

Figure F4 shows uncorrected TKN concentrations with corresponding method blanks for each of the gauging stations. Analyses for TKN were conducted using copper sulfate in the digestion solution through May 2007. Analyses were switched from the Alpkem instrument to the Bran+Luebbe instrument in June 2007. These changes showed less variability in the method blanks and lower overall concentrations. However, the plot illustrates that most TKN sample measurements were equivalent to or only slightly above blank levels. Therefore, most data were flagged in the database.

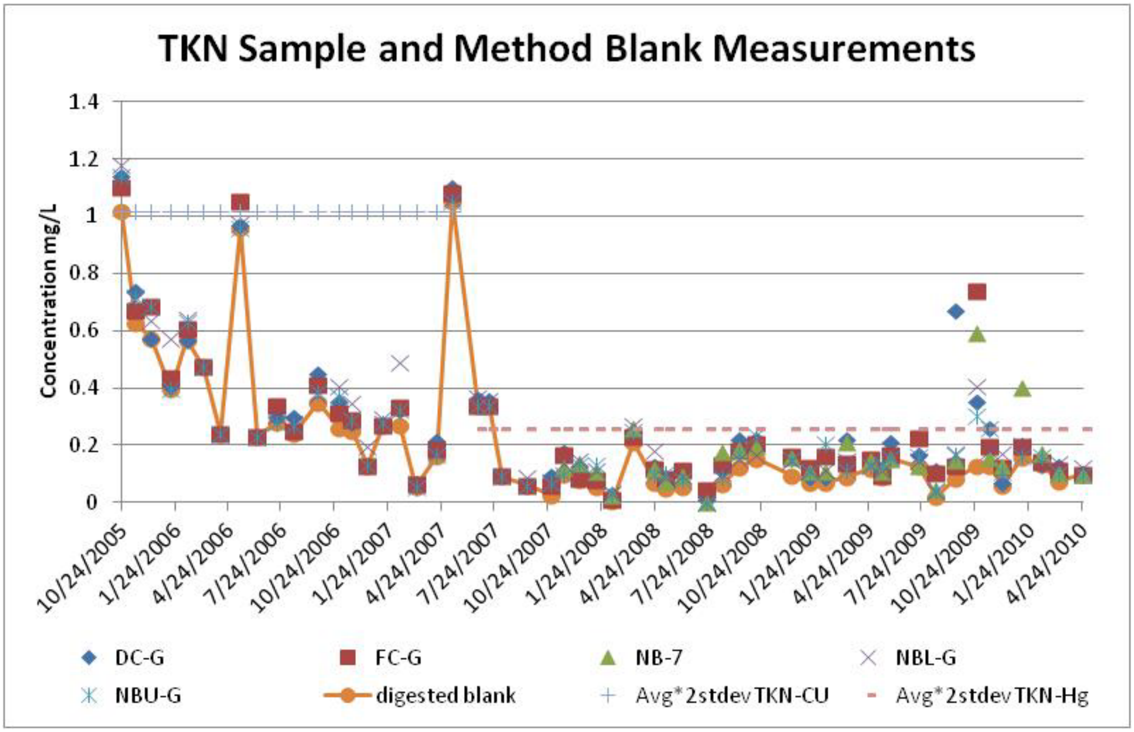

Figure F4. Sample and Method Blank TKN Measurements

Figure F5 provides MS recovery data for TKN analyses showing the number of measurements that failed to meet the 70-130% recovery criteria. The high number of measurements below 70% (14) suggests a low bias. These data further illustrate the problems associated with this analytical determination. Data were flagged where analyses failed MS recovery criteria.

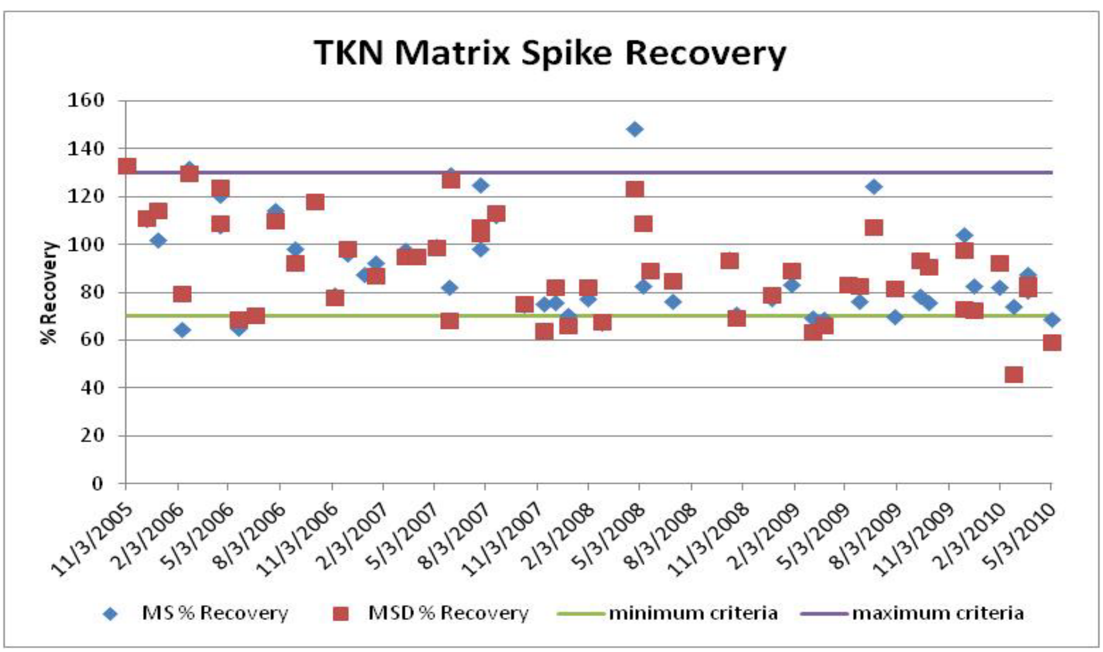

Figure F5. TKN Matrix Spike Recovery Data

TN QA/QC performance using an alkaline persulfate procedure is summarized in Table F9 representing analyses from June 2010 to March 2016. Four of the dCCVs were below 80%, four dCCVs exceeded 120%, and one dICV exceeded 120%; therefore, >96% of measurements passed the criteria. Two sets of duplicate MS recovery analyses exceeded 130%, as shown in Figure F6.

Table F9. TN Persulfate Procedure Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Digestion blank mg/L	74	0.07	0.04	0.03	0.16		0.14
ICV %Rec	146	98.0	2.32	87.0	104	93.3	103
CCV %Rec	145	96.8	2.36	86.0	102	92.1	102
dICV %Rec	70	102	5.09	89.2	122	91.4	112
dCCV %Rec	210	99.8	8.86	55.8	134	82.1	118
Sample %RPD	72	1.38	1.66	0.00	8.40		4.7
MS/MSD %Rec	143	102	10.0	86.0	156	82.3	122
MS/MSD %RPD	71	2.13	3.19	0.00	21.7		8.5

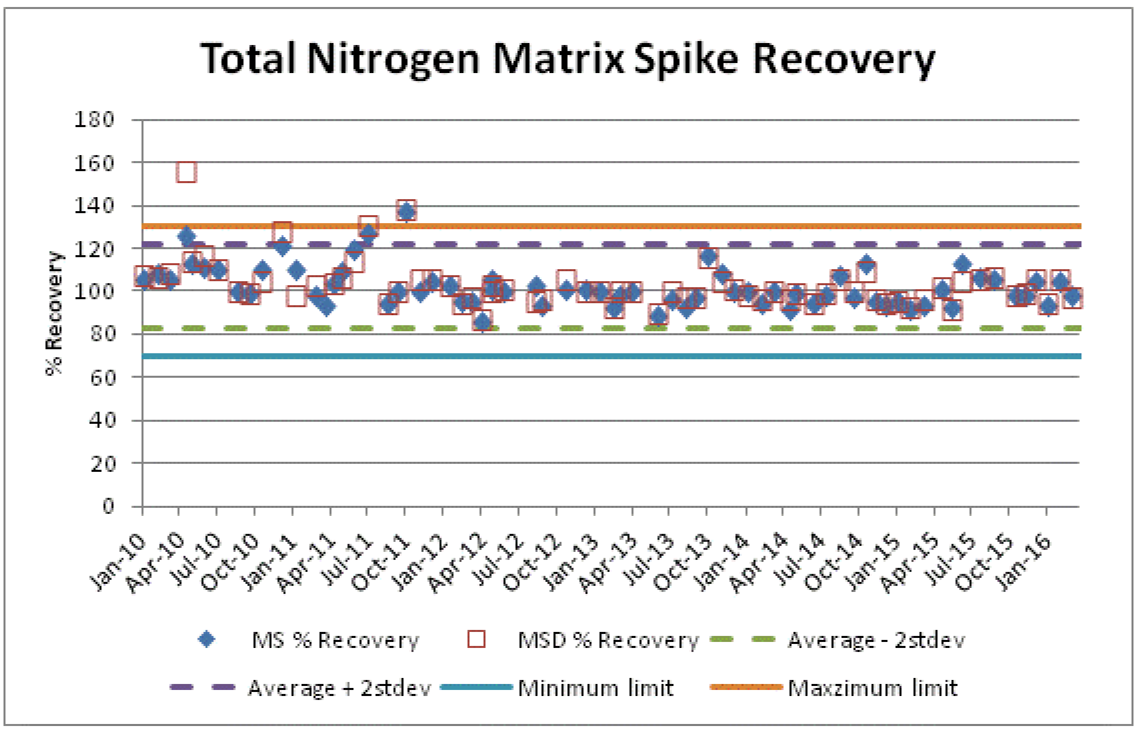

Figure F6. TN Matrix Spike Recovery Data

Orthophosphate QA/QC Summary

Orthophosphate QA/QC performance is presented in Table F10. The results show low analytical blanks and good recoveries of ICVs, CCVs, and MSs. Four duplicate measurements out of 116 had RPDs >25%. Results with and without these four measurements are included in the table for comparison.

Table F10. Orthophosphate Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Analytical Blank mg/L	124	0.00	0.007	0.00	0.04	NA	0.02
ICV %Rec	245	101	3.19	88.9	115	94.4	107
CCV %Rec	245	98.8	3.10	79.0	108	92.6	105
Sample %RPD	116	6.23	8.96	0.00	58.8[a]	NA	24
Sample %RPD[a]	112	4.91	5.36	0	25.0	NA	16
MS/MSD %Rec	240	98.8	4.28	80.8	117	90.2	107
MS/MSD %RPD	100	1.27	1.85	0	10.1	NA	5.0

[a] Four duplicate measurements >25% were removed for comparison of RPD.

Figure F7 shows orthophosphate MS and MSD recoveries for each monthly sampling. The results show that the recovery criterion of 70-130% was met for all sample sets in the study. Recoveries below 90% were associated with earlier instrumentation using the Alpkem analyzer.

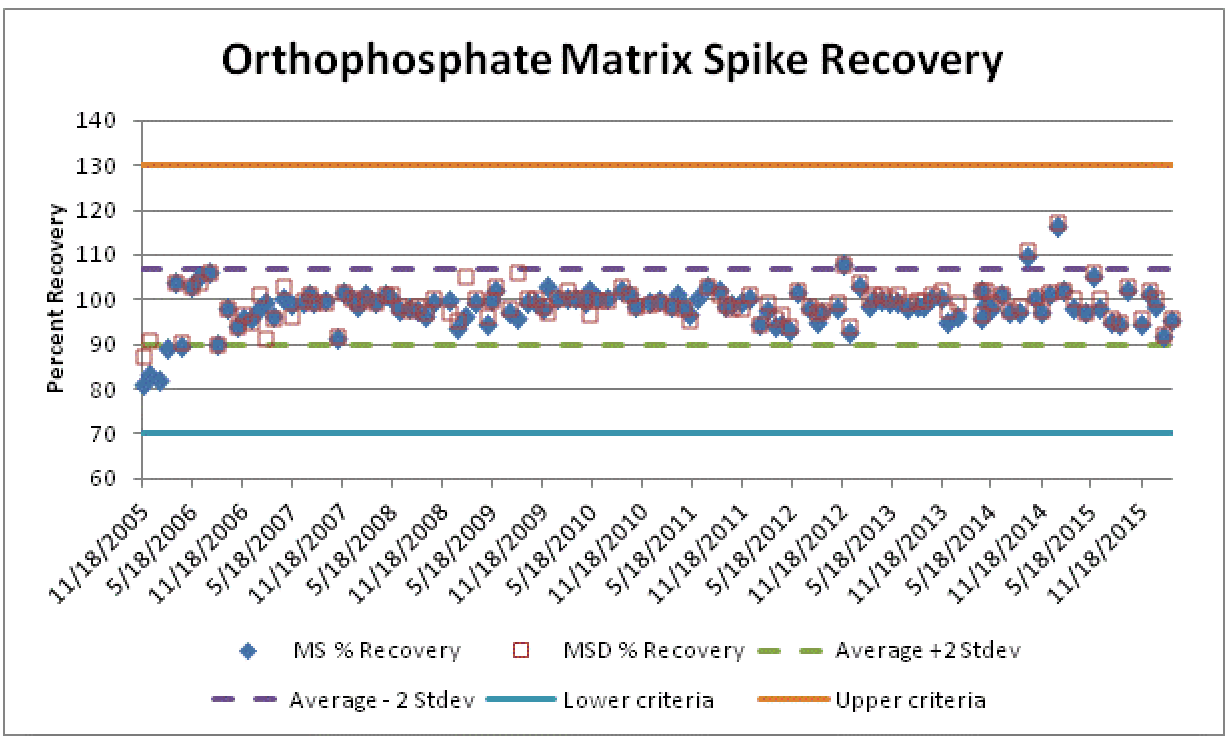

Figure F7. Orthophosphate Matrix Spike Recovery Data

TP QA/QC Summary

TP measurements were conducted using a copper sulfate Kjeldahl (TKP) digestion procedure and an Alpkem analyzer from October 2005 to June 2006. Analyses were conducted by an acidic persulfate procedure beginning in June 2006 because of high blank values and high variability associated with the Kjeldahl digestion procedure. TP QA/QC data for the nine data sets using Kjeldahl digestion are summarized in Table F11.

Table F11. Total Kjeldahl Phosphate Laboratory Quality Control Data

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
TKP-Cu digestion blank mg/L	9	0.19	0.06	0.14	0.31		0.31
ICV %Rec	15	106	8.62	98.6	130	89	123
CCV %Rec	15	103	11.6	94	144	79.3	126
dICV %Rec	5	114	12.7	95.6	131	114	139
dCCV %Rec	11	109	15.6	81.0	137	78	140
Sample %RPD	8	NA	NA	NA	NA	NA	NA
MS/MSD %Rec	18	106	22.8	58.2	132	60	151
MS/MSD %RPD	9	5.2	5.3	0.4	16.2		15.8

Method blanks and sample concentrations were highly variable from batch to batch, and sample measurements were not sufficiently above their corresponding method blank levels to reliably quantify results as illustrated by the nine TKP sampling episodes shown in Figure F8. In addition, three MS analyses were outside the 70-130% criteria.

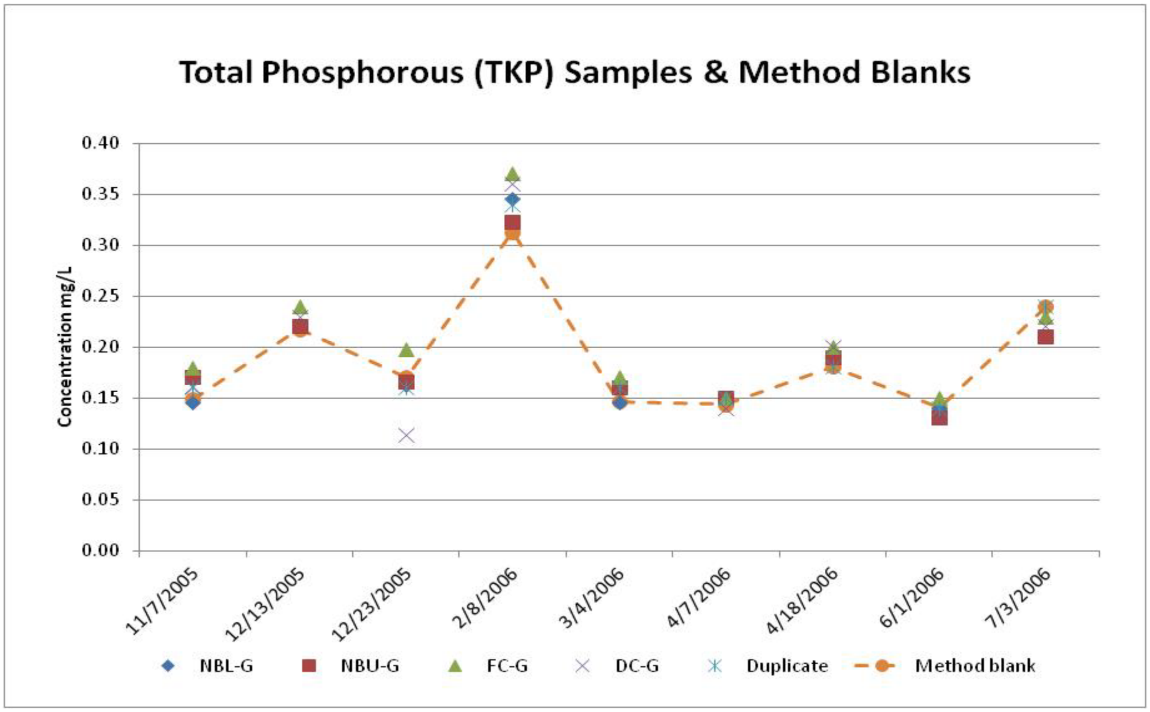

Figure F8. Total Kjeldahl Phosphorus Sample and Method Blank Data

Beginning in June 2006, TP analyses were conducted using an acidic persulfate digestion procedure (TPP). Data for QA/QC using this procedure are presented in Table F12 and show that method blank levels were considerably lower using this digestion technique than TKP digestion. All quality assurance measures were within accepted limits except four duplicate analyses where RPD was >25% and two dCCVs with recoveries <70%. Both dCCV spike levels were near the method detection limit. These data were flagged in the database.

Table F12. TP Persulfate Quality Control Summary

Quality Control Parameter	n	Average	Standard Deviation	Minimum	Maximum	Average −2 Std Dev	Average +2 Std Dev
Digested blank mg/L	102	0.01	0.006	0.00	0.02		0.02
ICV %Rec	200	100	3.14	93.0	116	94.0	107
CCV %Rec	201	98.8	2.76	87.8	106	93.3	104
dICV %Rec	98	100	4.30	82.9	113	91.8	109
dCCV %Rec	259	98.0	7.42	20.0	126	83.2	113
Sample %RPD	102	5.56	7.35	0.00	44.4[a]		20.3
MS/MSD %Rec	207	100	5.59	73.4	118	89.0	111
MS/MSD %RPD	102	1.57	1.50	0.00	7.3		4.6

[a] Four values >25%.

The MS and MS TPP duplicate recovery analyses in Figure F9 show that recoveries were all within acceptance limits, although there was slightly more variability when the Alpkem analyzer was used prior to June 2007.

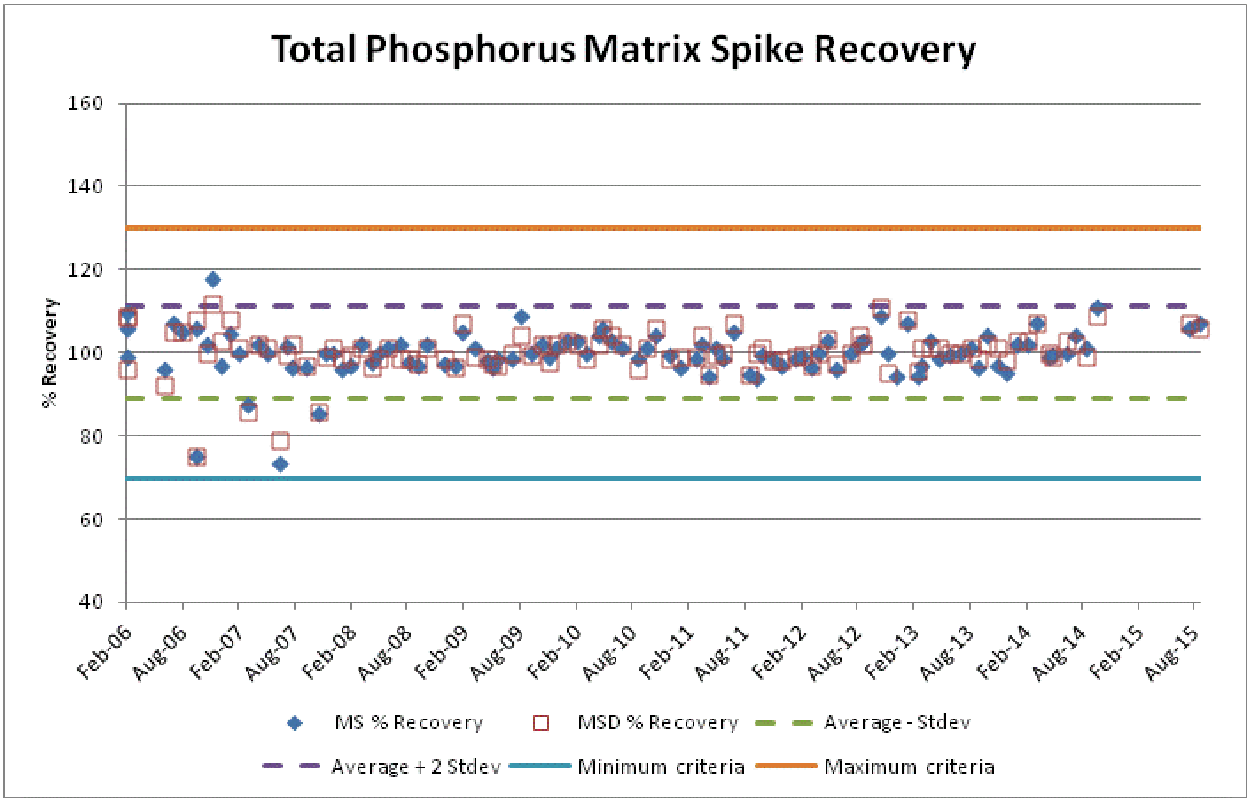

Figure F9. TP Persulfate Matrix Spike Recovery Data

Summary of Nutrient Data Quality

Nutrient samples were collected monthly at the gauging stations, with missing data representing less than 3% of total samples collected over the course of the study. Synoptic site sampling frequencies varied over the course of the study. Episodes where samples were not collected represented 18% of DCG synoptic sites, 2-12% of various FCG synoptic sites, and 2-7% of Needle Branch synoptic sites. Samples not collected because the stream segment was dry were primarily from tributary streams in July through September. Between October 2005 and September 2014, 39 Needle Branch sites were dry: NBU (1), NB-5 (2), NB-3 (8), UNB-A (3), UNB-B (4), and UNB-C (21). Fifteen FCG sites were dry: FC-5 (1), FC-3 (2), and FC-7 (12). Fourteen DCG sites were dry: DC-1A (2), DC-3 (5), and DC-8 (7).

Field duplicate precision passed acceptance criteria for all parameters with measurable concentrations except for 4 of 33 field duplicates analyzed for TP that exceeded 35% RPD. Field precision could not be determined for ammonia because results were at or near quantitation limits or blank levels and could not be determined for TP or TKN when copper sulfate digestion reagent was used because of highly variable blank levels.

Analytical performance for nutrients was assessed by conducting method blanks, ICV, CCV, sample duplicate analyses, matrix spikes (MS), and MSD with each analytical batch. When analyses required a digestion procedure, dICVs and dCCVs were taken through the entire analytical process. When sample results were at or near corresponding method blank levels or at the method quantitation limit, precision was assessed using the MS/MSD RPD.

Table F13 provides an overview of the results of these analyses. “Pass” indicates that all analyses met acceptance criteria or did not present interference problems. Method blank levels caused interference with low-level sample analyses for some nutrient parameters, influencing the reliability of low-level sample results. These data were flagged because concentrations measured in the samples were less than or equal to one times the method blank (B1) or less than or equal to two times the method blank (B2). Performance checks that failed to meet QA/QC acceptance criteria are shown in relation to the number of overall analyses performed. Precision includes both sample and MS/MSD duplicate RPDs.

Table F13. Nutrient Method Performance

Parameter	Method Blank	ICV	CCV	dICV	dCCV	Precision	Matrix Spike
Nitrate-nitrite	Pass	Pass	Pass	NA	NA	Pass	Pass
Ammonia	Blank flag	Pass	Pass	NA	NA	Pass	1/206
TKN	Blank flag	Pass	Pass	7/49	20/75	5/103	21/107
TNP	Pass	Pass	Pass	1/70	8/210	Pass	4/143
Orthophosphate	Pass	Pass	Pass	NA	NA	4/233	Pass
TKP	Blank flag	Pass	1/15	1/5	1/11	Pass	3/18
TPP	Pass	Pass	Pass	Pass	2/259	3/204	Pass

Conclusions

Overall, these data are of high data quality with very low instances of QA/QC performance failures except when Kjeldahl digestion procedures were used. Except for one CCV for TKP, all ICVs and CCVs met 80-120% acceptance criteria. More than 97% of dICVs and dCCVs also met these criteria, exclusive of Kjeldahl digestion data. Duplicate measurements passed the <25% RPD precision criterion more than 98% of the time, and MSs passed a 70-130% recovery criterion more than 98% of the time, exclusive of Kjeldahl digestion data. Results of nitrate-nitrite analyses are of the highest data quality, having passed all QA/QC performance criteria.

Ammonia analyses also passed all performance checks except one MS recovery that was outside the acceptance range. However, most ammonia concentrations measured in the samples were within three times the method blank levels and were flagged in the database as B1, B2, or B3, indicating a result was less than or equal to one, two, or three times the blank level, respectively. These measurements were discontinued in September 2014 because concentrations were too low to statistically evaluate these data before and after harvest or between control and harvest streams.

Data for TKN were unreliable due to high method blank levels compared with low sample concentrations and moderately high failure rates of method QA/QC, which is why these analyses were discontinued, and TN measurements using alkaline persulfate digestion (TNP) were initiated instead. Unfortunately, this will make it difficult to assess differences before and after harvest and among paired watersheds. Analyses of TNP passed >96% of QA/QC performance criteria for dICVs and dCCVs and >96% of MS recoveries. Concentrations of TN should be evaluated against nitrate-nitrite concentrations to determine whether there is a statistical difference in the results that indicates a sufficient organic nitrogen contribution that could be differentiated before and after harvest or between the control and harvest streams.

Orthophosphate analyses were also of high data quality. All QA/QC performance criteria were met except four sample duplicates with RPDs >25%.

Analyses for TP using the Kjeldahl digestion procedure were also unreliable due to high method blank levels compared with low sample concentrations. The TKP method was used for 9 months of the 10-year study summarized herein. These analyses were discontinued, and TP measurements using acidic persulfate digestion (TPP) were initiated. Measurements for TPP passed all ICV and CCV performance criteria, >99% of dICV and dCCV criteria, and 98% of all precision measurement criteria.

APPENDIX G

HERBICIDE STUDY SUMMARY

Derived from NCASI Special Report No. 13-01 as prepared by Jeff Louch, NCASI
Edited by Terry Bousquet, NCASI

Introduction

NCASI Special Report No. 13-01 (hereinafter SR13-01), prepared by Jeff Louch (NCASI 2013), summarized results of measurements of glyphosate, aminomethyl phosphoric acid (AMPA), imazapyr, sulfometuron methyl, and metsulfuron methyl in Needle Branch streamwater following an aerial herbicide application. This appendix summarizes the herbicide study data quality as discussed in that report. Data gaps related to the operations of the automated samplers were noted in the report. Those malfunctions affected the extent of analyses possible in the investigation, which is discussed herein.

The investigation was set up to manually trigger automated samplers when a storm approached. Multiple instances of sampler malfunction led to no samples or reduced numbers of samples collected during some storms, leading to a loss of data for some sample periods at some locations. Another unexpected result was lower than expected concentrations of glyphosate during the first storm at the upper site. In the second storm, the upper site had twice the concentration of the downstream site, which was the expected outcome during the first storm. We have no information to suggest those are not actual results, other than some of the other problems in automated sampler operation. One hypothesis is that because of dry antecedent conditions prior to the application, there was very little runoff at the uppermost weir, although available data do appear to show a descending limb at the beginning of data collection.

Study Overview

Study Site and Herbicide Treatments

Three herbicide monitoring stations were established in the Needle Branch drainage (Figure G1). The lowest elevation station (NBL) was near the mouth of Needle Branch and was the site of most water quality monitoring conducted in the original New Alsea Watershed Study (1959-1973). The middle elevation or upper station (NBU) was at the bottom of the first harvest unit and was established several years prior to the 2009 harvest to provide data on water quality immediately below the harvest unit. At this location, Needle Branch is a small, fish-bearing stream requiring a forested riparian management area of 50 ft from the ordinary high water mark on both sides of the stream and with minimal basal area retention requirements. The highest elevation station (Needle Branch H-flume [NBH]; H stands for an H-flume installed to monitor discharge) is at the fish/no-fish interface; there was no riparian buffer above NBH (forested riparian management areas are not required around most no-fish stream reaches in Oregon). A no-spray buffer is required around streams such as Needle Branch, including the previously mentioned no-fish/fish interface.

Prior to replanting, the upper portion of the study site (122 acres above NBU) received an aerial site-release application of herbicides. All herbicides were applied in a single tank mix at rates of 48 oz/ac of Accord XRT II (glyphosate), 12 oz/ac Chopper Gen 2 (imazapyr), and 4 oz/ac Sulfomet Extra (sulfometuron methyl and metsulfuron methyl), corresponding to 681 g/ac acid equivalents (a.e.) of glyphosate, 85 g/ac a.e. of imazapyr, 64 g/ac active ingredient (a.i.) of sulfometuron methyl, and 17 g/ac a.i. of metsulfuron methyl. The tank mix was applied by helicopter using a 32-ft boom with 35 D7 nozzles (no spinner) set at a 20° angle producing 22 psi. The application was initiated at 11:37 a.m. and completed at 1:18 p.m. on August 22, 2010. Analyses of these herbicides and AMPA, a glyphosate metabolite, were conducted on water samples collected from each site shown in Figure G1 during storm events.

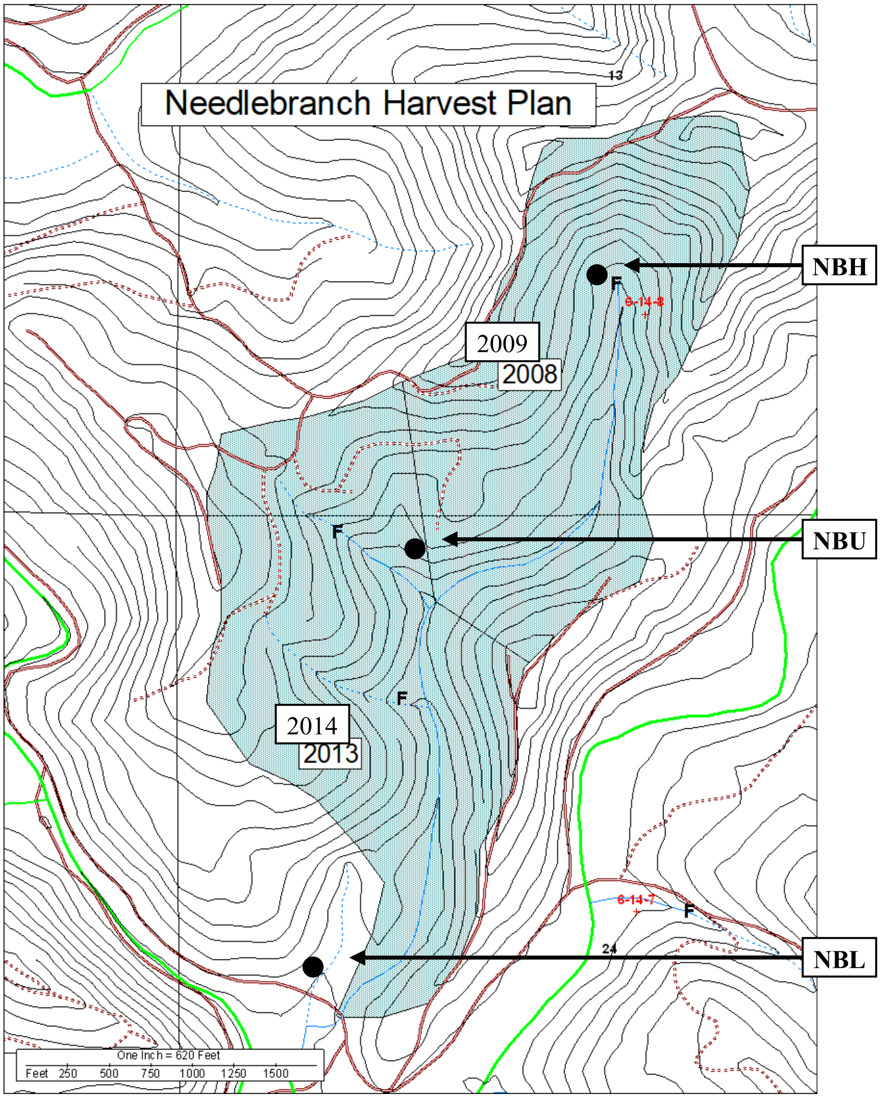

Figure G1. Herbicide Monitoring Stations Established in Needle Branch
[Notes: NBH = bottom of no-fish stream reach; NBU = bottom of harvest and spray unit; NBL = main gauge near mouth of watershed]

Sample Collection and Sample Count

Streamwater samples were collected during postapplication storm events at all three herbicide monitoring stations (henceforth, sampling sites) using Teledyne ISCO autosamplers. The samplers were manually triggered when a storm was predicted, and the sampling frequency was adjusted based on the predicted intensity and duration of each storm. Although these were subjective decisions, sampling frequency was highest (one sample per hour) when a high-intensity storm was predicted and was reduced (to as low as one sample every 6 hours) when a low-intensity event was predicted. Longer events required multiple triggerings of the autosamplers, and sampling frequency was often adjusted between cycles. During each sampling event, all samplers were programmed to initiate sample collection at the same time using the same sample collection rate. In addition to the storm event samples collected using the Teledyne ISCO samplers, baseflow grab samples were manually collected approximately every week.

The Teledyne ISCO samplers were also used to collect samples every hour during aerial herbicide application. Specifically, collection was initiated at 9 a.m., and the samplers were programmed to collect additional samples every hour. Thus, three samples were collected before the application was initiated at 11:37 a.m., and sampling continued for nominally 20 hours after application.

Table G1 summarizes the final sample count per sampling site. Samples for determination of imazapyr, sulfometuron methyl, and metsulfuron methyl were preserved at pH 7 at the time of collection. Samples for determination of AMPA and glyphosate were not pH preserved but were frozen for long-term storage.

Table G1. Number of Samples Collected from Each Sampling Site as Part of Each Sampling Event

Sampling Dates				Unpreserved Samples			pH 7 Preserved Samples		
Start	End	DAT[a]	Event	NBL	NBU	NBH	NBL	NBU	NBH
08/22/10	08/23/10	0	Baseflow[b]	24	4[c]	24	24	24	1[d]
08/25/10		3	Baseflow	1	1	1	1	1	1
08/30/10	09/01/10	8-10	Storm	45	48	46	0[e]	48	48
09/10/10		19	Baseflow	1	1	1	1	1	1
09/14/10		23	Baseflow	1	1	1	1	1	1
09/15/10	09/21/10	24-30	Storm	53	54	54	54	54	54
09/24/10		33	Baseflow	1	1	1	1	1	1
10/01/10		40	Baseflow	1	1	1	1	1	1
10/08/10		47	Baseflow	1	1	1	1	1	1
10/08/10	10/10/10	47-49	Storm	0[f,g]	14[g]	14[g]	19	19	19
10/14/10		53	Baseflow	1	1	1	1	1	1
10/22/10		61	Baseflow	1	1	1	1	1	1
10/23/10	10/25/10	62-64	Storm	11[h]	23	24	23	23	24
11/05/10		75	Baseflow	1	1	1	1	1	1
11/18/10	11/19/10	88-89	Storm	11	15	15	15	14	15
11/20/10		90	Baseflow	1	1	1	1	1	1
12/03/10		103	Baseflow	1	1	1	1	1	1
12/10/10	12/12/10	110-112	Storm	27	6[i]	9[i]	36	25	30
				182	175	196	182	218	202

[a] DAT = days after treatment (application of herbicides).
[b] Teledyne ISCO samplers collected one sample per hour starting 3 hours prior to application of herbicides during baseflow conditions.
[c] Teledyne ISCO sampler collected samples 1-3 and then malfunctioned; an additional grab sample was collected ≈24 hours after application of herbicides.
[d] Teledyne ISCO sampler malfunctioned; single grab sample collected ≈24 hours after application of herbicides.
[e] Teledyne ISCO sampler malfunctioned.
[f] Teledyne ISCO sampler malfunctioned during first portion of storm event.
[g] Samples collected by Teledyne ISCO samplers during second portion of storm event were not retained.
[h] Teledyne ISCO sampler malfunctioned after collecting 10 samples; additional grab sample collected at end of storm event.
[i] Reduced number of NBU and NBH samples retained during first portion of storm event; none retained from second portion.

As shown in Table G1, in multiple instances sampler malfunction led to either no samples or reduced numbers of samples being collected during a specific storm event. In addition, some samples collected during later storm events were not retained. Specifically, only a subset of the samples for determination of AMPA and glyphosate (unbuffered samples) collected during the October 8-10, 2010, and December 10-12, 2010, storm events were retained. This decision was informed by analytical results showing that AMPA and glyphosate were not detected in earlier storm events. This was also the basis for terminating collection of samples for determining concentrations of imazapyr, sulfometuron methyl, and metsulfuron methyl after the December 10-12, 2010, storm event.

Sample Collection and Stage Data

Figure G2 shows stage (water height at the flume) data for NBL covering the period over which most samples were collected. (Although a limited number of samples collected after October 27, 2010, were analyzed and results are reported in the appropriate appendices of SR13-01, those samples are not shown in the figure.) The figure also shows when storm event and baseflow samples were collected for determination of herbicide concentrations. As noted in the previous section, samples were collected at all three sites at the same time. That is, each sample point shown in Figure G2 represents a sample collected at NBH, NBU, and NBL.

NBL stage data clearly reflect the effect of each storm event. More importantly, the figure also shows that the sample collection regimen effectively sampled each storm event.

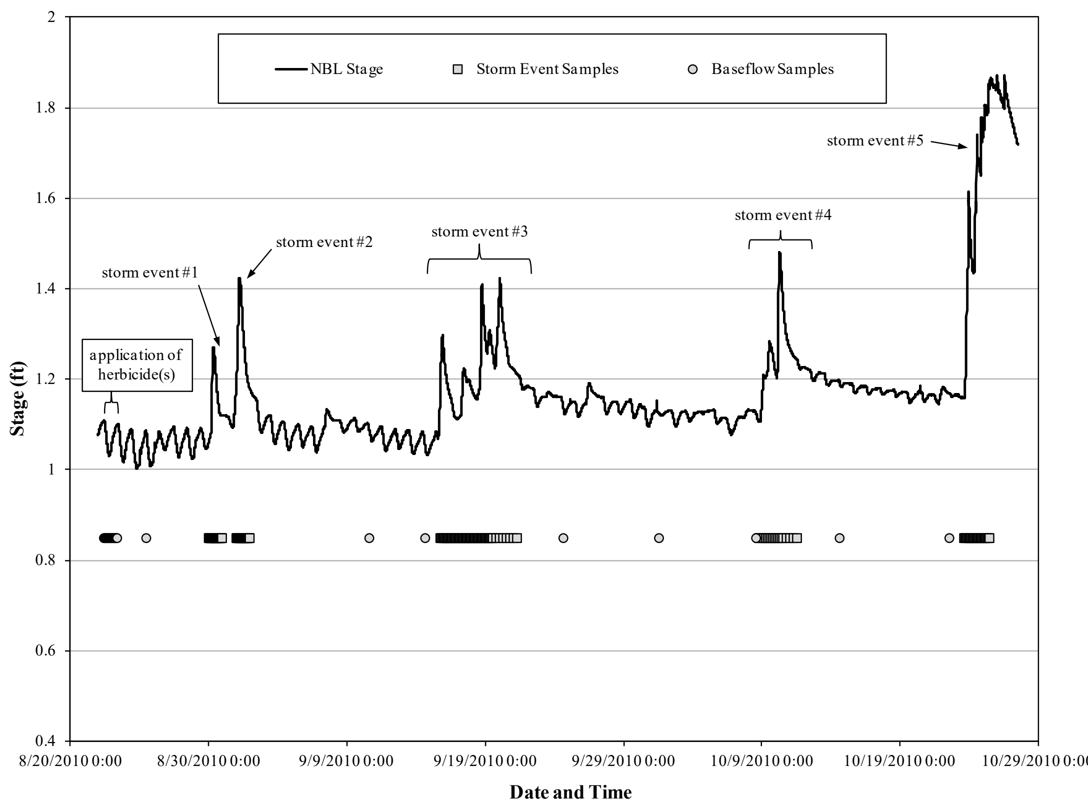

Figure G2. Stage Level at NBL from August 22 through October 27, 2010, with Identification of All Sampling Events

Herbicide Data Quality Discussion

Herbicide presence was analyzed via liquid chromatography tandem mass spectrometry (LC/MS-MS). Calibration and instrument setup are discussed in SR13-01. Method detection limits (MDLs) for each herbicide were determine via replicate analyses of a single baseflow sample collected at NBL immediately prior to herbicide application in August 2010. Background interferences and MDLs for each parameter are discussed in the following subsections.

Glyphosate and AMPA Detection Limits and Interferences

The MDLs for both AMPA and glyphosate reflect the effect of background interference at sample concentrations equivalent to ≈2 ng/L AMPA and ≈13 ng/L glyphosate (a.e.). Ultimately, it was shown that the interference for both analytes varied from sample to sample. The interference affecting AMPA was as high as ≈7 ng/L (as AMPA) in some samples, while the interference affecting glyphosate reached ≈40 ng/L. Under these circumstances, the cited MDLs provide academic measures of method performance. That is, true analyte-specific MDLs were affected by the presence of variable background interference such that the MDLs varied from sample to sample.

More importantly, the inability to discriminate these interferences means that all concentrations from NCASI's analyses carry some high bias unless each result is background subtracted. However, because the levels of interference affecting both AMPA and glyphosate were shown to vary on a sample-specific basis, background subtraction was not defensible. Compounding this dilemma, study-specific quality assurance (QA) showed losses of both analytes over the analytical process. Recovery of AMPA from the analysis was on the order of 80% (20% loss). However, all measured AMPA concentrations were low enough (<12 ng/L) to be affected by background interference. The level of this interference was as high as ≈7 ng/L (as AMPA) in some samples, indicating that all measured concentrations could carry >50% high bias. Thus, the AMPA concentrations are considered to carry a net high bias. Recovery was on the order of 90% (10% loss) for glyphosate, and measured glyphosate ranged from ≈18 (i.e., not detected) to ≈150 ng/L. As noted, the interference affecting glyphosate was shown to range from ≈13 to ≈40 ng/L. Thus, even at the highest concentrations found in this study, high bias almost certainly outweighed low bias, meaning that glyphosate concentrations are also considered to carry a net high bias.

In the broadest sense, this situation reflects the limitations of high performance liquid chromatography (HPLC) with fluorescence (FLUOR analysis (HP/FLUOR) vs. liquid chromatography-mass spectrometry (LC/MS) (or LC/MS-MS) analysis (Hanke et al. 2008). More specifically, an LC/MS-MS analysis has greater potential to discriminate interference from chromatographic co-elutors as a result of better selectivity (mass spectrometry vs. fluorescence). Thus, when sample splits were submitted for confirmatory analysis by LC/MS-MS, glyphosate concentrations from NCASI's LC/FLUOR analysis were shown to be high biased by anywhere from 6.6 to 42 ng/L, corresponding to a 25-100% high bias on a sample-specific basis. Because the LC/FLUOR analysis is actually more sensitive than an LC/MS-MS analysis, all of NCASI's AMPA results were less than the LC/MS-MS reporting limit and so could not be confirmed by LC/MS-MS analysis.

Imazapyr, Sulfometuron Methyl, and Metsulfuron Methyl Detection Limits and Interferences

The MDLs for imazapyr, sulfometuron methyl, and metsulfuron methyl also reflect the effect of background interference at sample concentrations equivalent to ≈0.1 µg/L imazapyr (a.e.), ≈0.2 µg/L sulfometuron methyl (a.i.), and ≈0.4 µg/L metsulfuron methyl (a.i.). As with AMPA and glyphosate, results showed that the magnitudes of the analyte-specific interferences varied from sample to sample. However, sulfometuron methyl and metsulfuron methyl were not detected in any sample at concentrations above the MDLs, so the issues around background interference and bias are moot.

Imazapyr was detected in only a handful of samples, and all measured concentrations were low enough (≤0.4 µg/L) to be affected by background interference, which results showed to be as high as ≈0.2 µg/L in some samples. Because this interference was known to vary from sample to sample, background subtraction was not performed. Imazapyr recovery was ≈80% at the concentrations found in samples (≤0.4 µg/L), indicating that high bias due to background interference almost certainly overwhelmed low bias due to losses incurred during analysis.

The situation with imazapyr is generally analogous to that for AMPA and glyphosate, and there are laboratories that use LC/MS-MS for determination of imazapyr (and sulfometuron methyl and metsulfuron methyl). However, no LC/MS-MS confirmatory analyses were performed for these analytes. Thus, all that can be said is that all reported imazapyr concentrations carry unknown high bias.

Discussion of Herbicide Results

Herbicides in Streamwater During Application

Dissolved glyphosate results from sampling during herbicide application are presented in Figure G3 and show a clear pulse (or spike) in dissolved glyphosate at NBH during application. Because there are measured values reflecting site-specific background immediately prior to application of glyphosate, issues regarding background subtraction are potentially moot, suggesting that the mean of these event- and site-specific background values can be subtracted from the associated event- and site-specific results. This preapplication background averaged 16.7 ± 1.9 ng/L (n = 3)[1] as glyphosate, giving a background-corrected maximum concentration of 45 ng/L. However, it is possible that the background was dynamic even over the limited period of time during which these samples were collected (e.g., the background might vary diurnally), so the background-corrected result could still carry unknown bias. Thus, it is simpler to accept the uncorrected result (62 ng/L) as a high-biased estimate of the maximum concentration. In any case, results show that the maximum concentration manifested in the first sample collected after application was initiated and that concentrations dropped to preapplication background in nominally 6 hours. That is, the pulse of dissolved glyphosate lasted no more than 6 hours, and the maximum concentration persisted for no more than 2-3 hours.

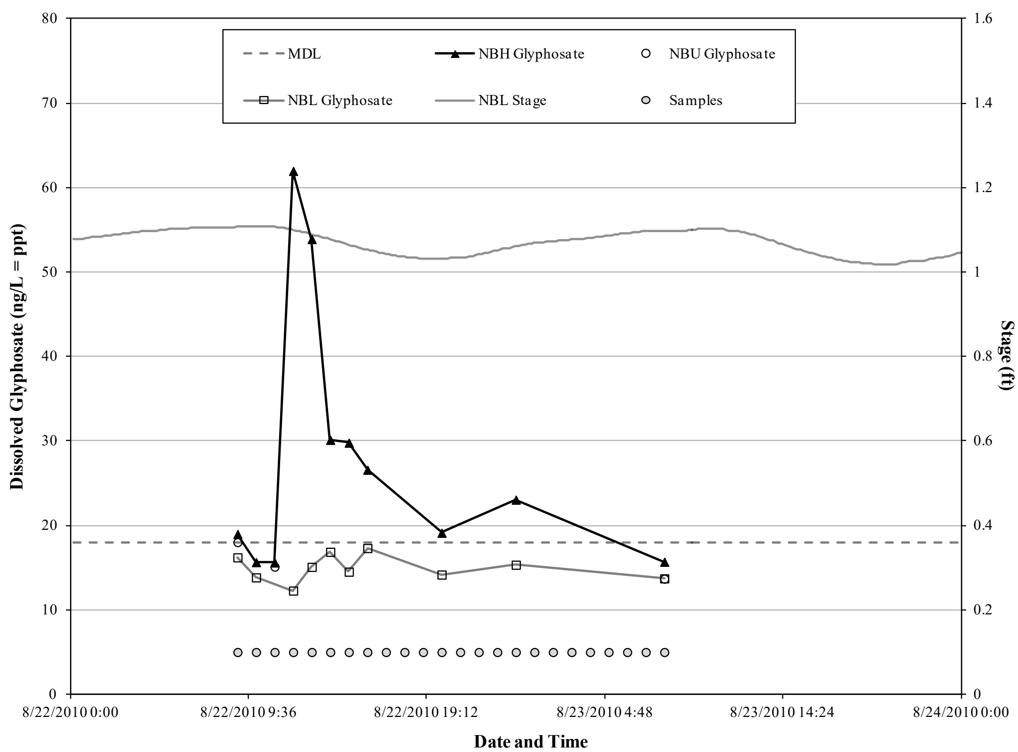

Figure G3. Dissolved Glyphosate in Streamwater (baseflow) Collected at NBH, NBU, and NBL During Application of Herbicides (all concentrations plotted regardless of MDL)

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[1] This background is higher than the mean obtained from replicate analyses of both refrigerated and frozen blank control sample, which averaged 13 ng/L and 12.8 ng/L, respectively, again showing that the background interference acting on glyphosate was variable.

Dissolved glyphosate at NBL remained at concentrations at or below the MDL (i.e., all reported concentrations were <18 ng/L) during the application period. The Teledyne ISCO sampler at NBU malfunctioned after collecting the first three samples, which reflects preapplication background only. These three samples gave concentrations nominally equivalent to those found in the corresponding NBH and NBL samples (Figure G3), as did a sample collected at NBU ≈20 hours after application.

As might be expected, AMPA was not detected in any sample collected during application (i.e., all samples returned <4 ng/L dissolved AMPA). As noted previously, sulfometuron methyl and metsulfuron methyl were not detected in any samples collected during this study.

However, as shown in Figure G4, some baseflow samples collected at NBU during the application gave results for dissolved imazapyr exceeding the MDL (0.2 µg/L), which was based on measurements made in the blank control (a preapplication baseflow sample collected at NBL). However, the highest concentration found in any of these samples was 0.31 µg/L, less than twice the mean site-specific preapplication background signal (≈0.2 µg/L; Figure G4) and well below the lower calibration level (LCL) of the initial calibration (ICAL), which was 0.6 µg/L. These factors suggest that all concentrations shown in Figure G4 reflect variability in the site-specific background interferent known to be present, not the presence of dissolved imazapyr. The fact that these results (Figure G4) do not show a clear pulse in dissolved imazapyr as was seen for glyphosate (Figure G3) is additional evidence that imazapyr was not present in these samples.

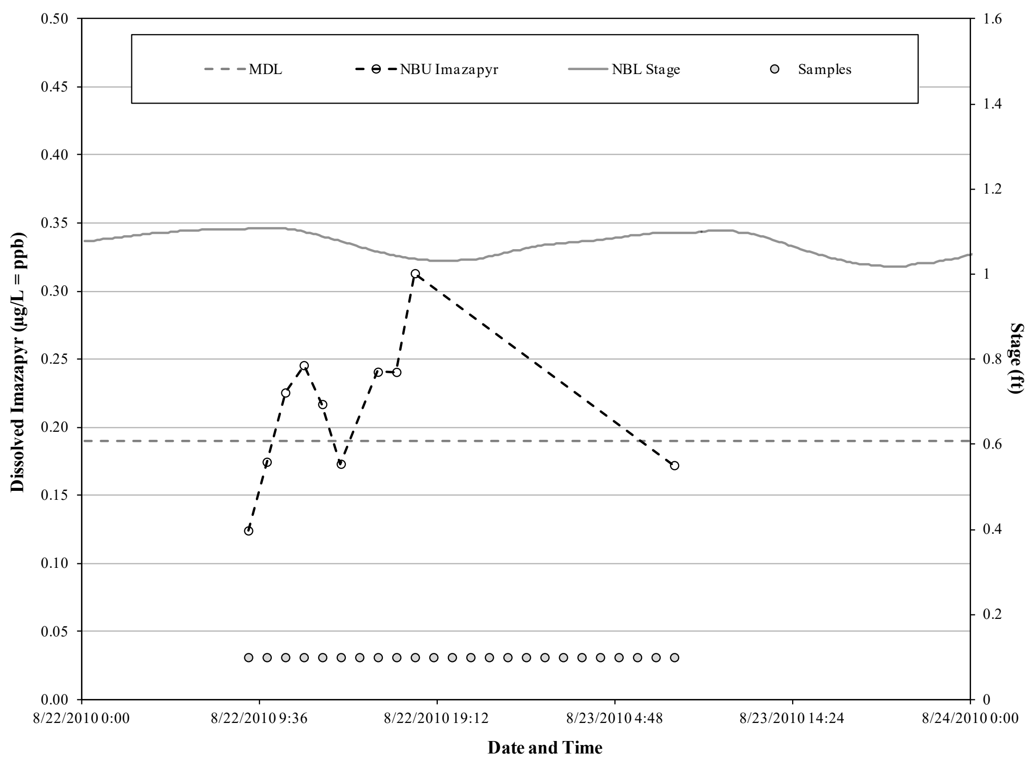

Figure G4. Dissolved Imazapyr in Streamwater (baseflow) Collected at NBU During Application of Herbicides (all concentrations plotted regardless of MDL)

Unfortunately, the Teledyne ISCO sampler at NBH malfunctioned during this sampling episode, so there are no imazapyr data for that site. Based on results at NBU, it was decided that there was no purpose in analyzing the NBL samples. Thus, results shown in Figure G4 are the only data indicating whether dissolved imazapyr manifested in baseflow during the application, and they support the absence of imazapyr during this period. Ultimately, however, given the uncertainties around variability in the background interferent and the fact that all measured concentrations were less than the ICAL LCL, the most defensible statement concerning these samples is that dissolved imazapyr was <0.6 µg/L (i.e., the ICAL LCL) in all of them.

Dissolved Herbicides in Baseflow

All samples returned nondetects for sulfometuron methyl (MDL = 0.5 µg/L) and metsulfuron methyl (MDL = 1 µg/L), so these herbicides were not detected in any baseflow sample. Thus, the only statement that can be made concerning these herbicides is that dissolved concentrations in baseflow never exceeded the specific MDLs.

In the first set of postapplication baseflow samples, collected 3 days after application (days after treatment, or DAT), imazapyr was detected at 0.2 µg/L at NBH but was not detected (<0.2 µg/L) at NBU or NBL. The second set of baseflow samples was collected 19 DAT, and imazapyr was detected at 0.2 µg/L at NBU but was not detected (<0.2 µg/L) at NBH or NBL. Thereafter imazapyr was not detected in any baseflow sample collected at any site out to 33 DAT, at which point analyses of baseflow samples for determination of imazapyr, sulfometuron methyl, and metsulfuron methyl were discontinued. None of these results can be taken as definitive evidence for the presence of dissolved imazapyr, and ultimately, the most defensible statement that can be made is that dissolved imazapyr was <0.6 µg/L in all of these samples.

Measured concentrations of dissolved glyphosate in baseflow samples were also low, ranging from nondetect (<18 ng/L) to 34 ng/L. These results are shown in Figure G5, which also shows results from the LC/MS-MS confirmation analysis performed on selected samples.

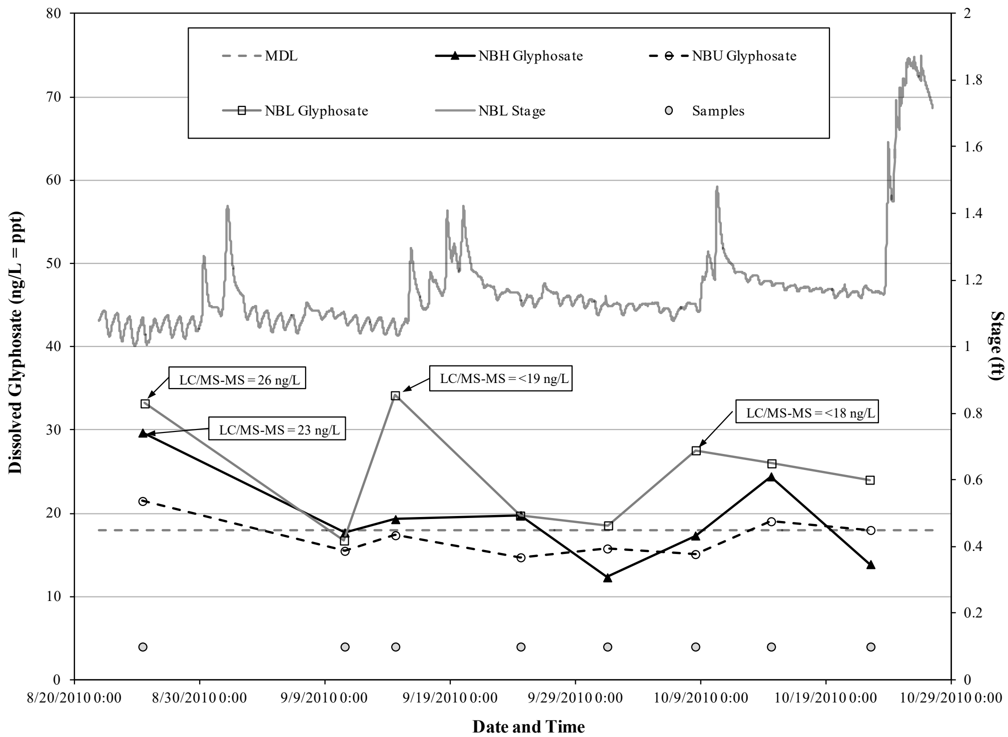

Figure G5. Dissolved Glyphosate in Baseflow Samples Collected at NBH, NBU, and NBL with Results from LC/MS-MS Confirmations (all concentrations plotted regardless of MDL)

Figure G5 shows that LC/MS-MS analyses always returned lower concentrations than those found by NCASI's analyses, again illustrating that NCASI's results are high biased. The LC/MS-MS results also confirmed the presence of dissolved glyphosate in the first baseflow samples collected at NBH and NBL after application of herbicides, which were collected on August 25, 2010 (3 DAT). Based on LC/MS-MS results, dissolved glyphosate was present at nominally 25 ng/L in these baseflow samples (3 DAT). NCASI's results show that dissolved glyphosate concentrations dropped to <20 ng/L by the second baseflow sampling (September 10, 2010, 19 DAT). Although some of NCASI's results were >20 ng/L in subsequent baseflow samples, the LC/MS-MS results effectively show that dissolved glyphosate remained at concentrations <20 ng/L in baseflow samples collected after September 10, 2010 (19 DAT). Overall, these results show that dissolved glyphosate in baseflow was ≈25 ng/L for a few days immediately following application of herbicides and dropped to <20 ng/L by 19 DAT, by which time two storm events had impacted the study site.

The first baseflow samples collected at NBH, NBU, and NBL following application returned 6-7 ng/L dissolved AMPA. All subsequent baseflow samples from NBH and NBU returned nondetects (i.e., reported results <4 ng/L). However, AMPA concentrations in subsequent NBL baseflow samples were variable, ranging from <4 to 8 ng/L.

These results suggest the presence of up to 6-7 ng/L dissolved AMPA in baseflow for a few days immediately following application of herbicides, and that concentrations at NBH and NBL dropped to <4 ng/L by 19 DAT. They also suggest that dissolved AMPA in NBL baseflow remained at concentrations in the range of 4-8 ng/L out to 75 DAT. However, all measured AMPA concentrations at all three sites were low enough to be biased by background interference, which is known to be as high as 7 ng/L (as AMPA) in samples, and all were well below the 15 ng/L ICAL LCL. Ultimately, because of the uncertainties concerning sample-to-sample variability in the background signal and the fact that all measured concentrations were below the ICAL LCL, the most defensible conclusion to be drawn from these results is that dissolved AMPA was <15 ng/L in all postapplication baseflow samples.

Dissolved Herbicides in Streamwater During First and Second Storm Events After Application

Figure G6 shows dissolved glyphosate results for samples collected at all three sites during the first two postapplication storm events. These storms occurred on August 30, 2010 (8 DAT), and September 1, 2010 (10 DAT). The results clearly show pulses of dissolved glyphosate at NBU during the August 30, 2010, storm event and at NBH during the September 1, 2010, storm event.

Although it cannot be proven, the absence of any observable pulse at NBH during the first storm event might be attributed to triggering the autosamplers too late (i.e., the highest concentrations at NBH could have manifested before sample collection was initiated). Certainly, the absence of a pulse at NBH during this first storm event is inconsistent with results obtained during the second storm event, which showed a clear pulse at NBH and only suggestions of pulses at the other two sites. Regardless, results from the second storm event suggest that any glyphosate pulse at NBH during the first storm event would have shown a maximum concentration on the order of twice the concentration seen at NBU. That is, the maximum concentration would have been approximately 300 ng/L. However, this estimate does not account for the potential effect of background interference on measured glyphosate, and ultimately, the apparent behavior of glyphosate at NBH during the first storm event remains inexplicable.

A number of the samples represented in Figure G6 were submitted for analysis by LC/MS-MS, and results from these confirmation analyses are included in the figure. Comparing NCASI's results to those obtained via LC/MS-MS analysis confirms that NCASI's results are high biased and that the absolute magnitude of this bias is sample specific. Thus, the LC/MS-MS results show that the maximum concentration at NBU during the August 30, 2010, storm event was 115 ng/L, not 149 ng/L (NCASI result biased high by 34 ng/L). LC/MS-MS results also show that the maximum concentration at NBH during the August 30, 2010, storm event was 42 ng/L instead of the 84 ng/L from NCASI's analysis (NCASI result biased high by 42 ng/L).

Of greater significance, the samples showing the highest concentrations found by NCASI at NBL during the two storm events, 51 ng/L and 48 ng/L on August 30, 2010, and September 1, 2010, respectively, returned nondetects at 19 ng/L by the LC/MS-MS analysis. This supports the conclusion that dissolved glyphosate was <20 ng/L in all NBL samples collected during these two storm events. In addition, LC/MS-MS analysis of the sample with the second highest concentration found by NCASI at NBU during the September 1, 2010, storm event also returned a nondetect (<18 ng/L) from the LC/MS-MS analysis. This supports the conclusion that dissolved glyphosate was <20 ng/L in all NBU samples collected during the September 10, 2010, storm event.

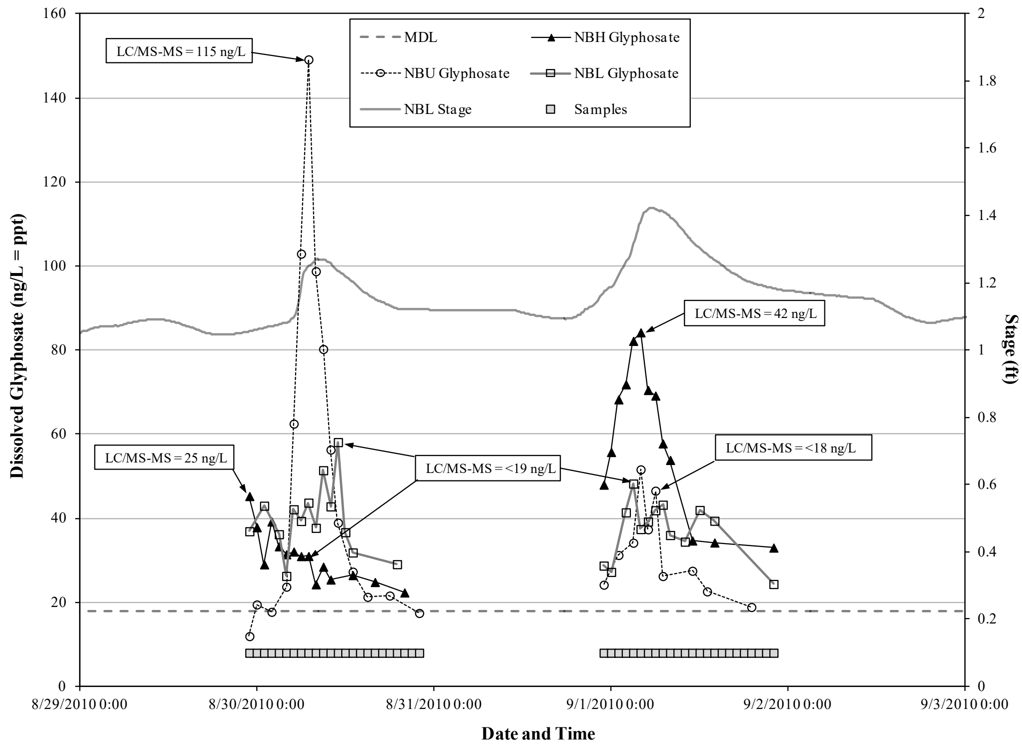

Figure G6. Dissolved Glyphosate at NBH, NBU, and NBL During First Two Storm Events After Application of Herbicides with Results from LC/MS-MS Confirmations (all concentrations plotted regardless of MDL)

Figure G7 shows results for dissolved AMPA from the same samples shown in Figure G6. Many returned nondetects (<4 ng/L), indicating that the sample-specific result was no greater than the mean background found in the frozen blank control. In addition, most measured concentrations were less than three times the mean background found in the same frozen blank control (2.4 ng/L), and all were less than the 15 ng/L ICAL LCL (thus, all measured AMPA concentrations must be considered estimates). Beyond this, there was no clear pulse in dissolved AMPA at any site during either storm event, with the possible exception of NBH during the second storm event. This observation alone suggests that there was no measurable AMPA in any of these samples and that all that was being measured was the background interferent. Thus, the results shown in Figure G7 could be interpreted as demonstrating that this interferent varied from site to site during these storm events. However, without additional data, this is only speculation. Ultimately, the most defensible statement regarding dissolved AMPA is that concentrations in streamwater collected at all three sites during these two storm events were <15 ng/L.

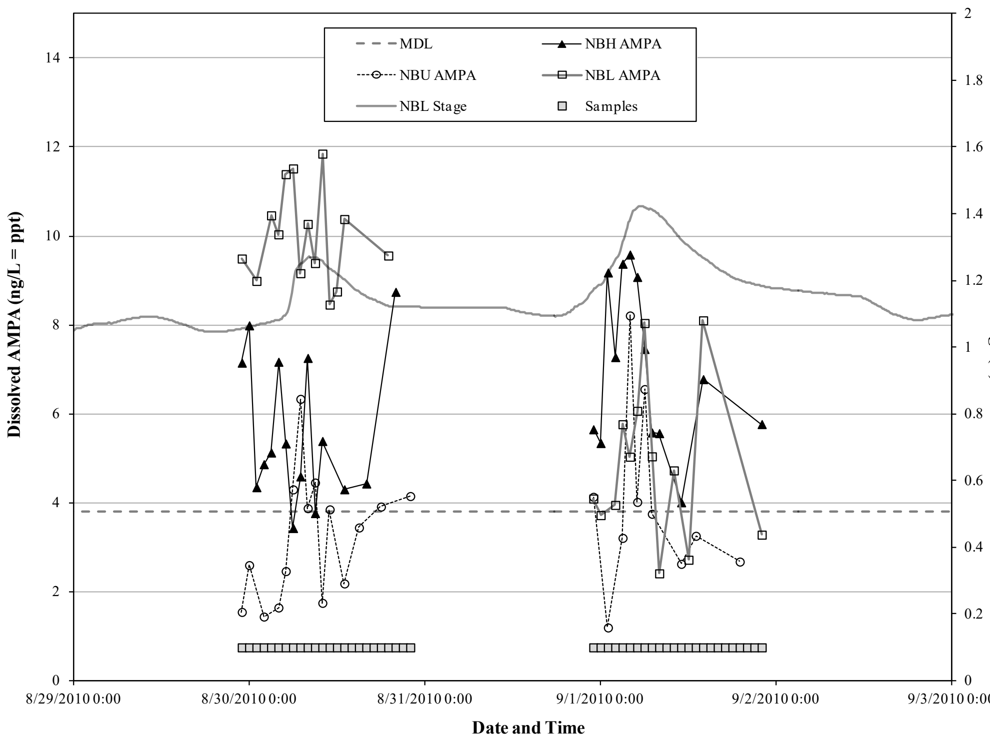

Figure G7. Dissolved AMPA at NBH, NBU, and NBL During First Two Storm Events After Application of Herbicides (all concentrations plotted regardless of MDL)

As noted, all samples returned nondetects for sulfometuron methyl (MDL = 0.5 µg/L) and metsulfuron methyl (MDL = 1 µg/L), so these herbicides were not detected in any samples collected during any storm event. Thus, the only statement that can be made concerning these herbicides is that dissolved concentrations in streamwater influenced by storm runoff never exceeded specific MDLs.

Measured imazapyr concentrations in samples collected at NBH and NBU during the first two postapplication storm events ranged from <0.2 µg/L (i.e., not detected above the mean background found in the blank control) to 0.4 µg/L. Thus, all measured dissolved imazapyr concentrations were low enough to be biased by the background interferent known to be present in all samples and were also below the 0.6 µg/L ICAL LCL. In addition, results showed no clear imazapyr pulse as was observed for glyphosate (Figure G6), indicating that the measured concentrations reflected variability in the background signal. Overall, these results can be taken as evidence of the absence of measurable dissolved imazapyr in streamwater at NBH and NBU during these storm events (the Teledyne ISCO sampler at NBL malfunctioned during these sampling events). However, as with dissolved AMPA, this is a hypothesis, and the most defensible conclusion is that dissolved imazapyr was always <0.6 µg/L in these storm event samples.

Dissolved AMPA and Glyphosate in Streamwater During Third Storm Event After Application

Figure G8 shows results for dissolved glyphosate in samples collected at all three sites during the third postapplication storm event. This storm started on September 15, 2010 (24 DAT), and continued through September 21, 2010 (30 DAT). These results show no evidence for the kind of pulse in dissolved glyphosate seen during the first two postapplication storm events (Figure G6), and with a handful of exceptions, all concentrations were less than three times the mean concentration found in the frozen blank control. This suggests that these measured concentrations reflect the variable background interferent known to be present in samples. This is supported by results from the LC/MS-MS confirmation analysis, which returned nondetects (<20 ng/L) for the two samples submitted. This outcome is significant, as one of these samples (from NBH) returned the highest concentration (62 ng/L) from NCASI's analysis of any sample from this storm event. Overall, these results support the statement that dissolved glyphosate was <20 ng/L in streamwater at all three sites during the third storm event.

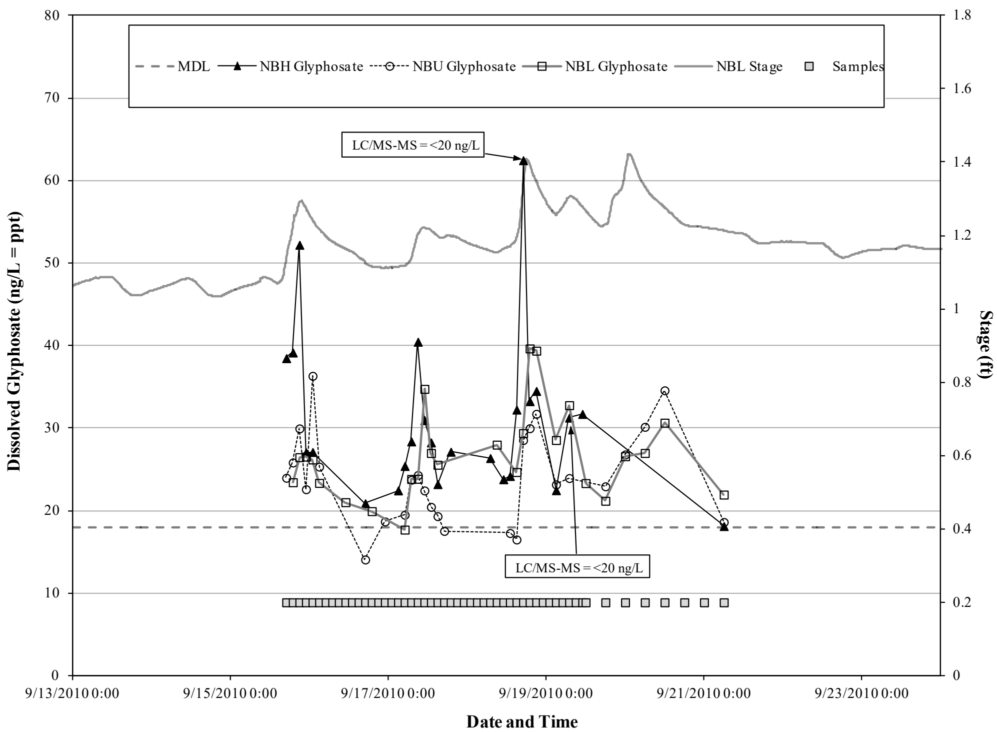

Figure G8. Dissolved Glyphosate at NBH, NBU, and NBL During Third Storm Event After Application of Herbicides with Results from LC/MS-MS Confirmations (all concentrations plotted regardless of MDL)

Concentrations of dissolved AMPA measured by NCASI in these samples ranged from <4 to 9 ng/L. As with the baseflow samples and samples collected during the first and second storm events, all these concentrations were low enough to be affected by the background interferent known to be present in samples and are less than the ICAL LCL (15 ng/L). In addition, as observed in the results from the first and second storm events, there was no pulse in dissolved AMPA at any site during the third storm event.

Overall, it is highly probable that there was no measurable AMPA in any of the samples collected during the third storm event and that what was being measured was the background interferent. Again, however, without additional data, this is only speculation. Thus, the most defensible statement regarding dissolved AMPA is that concentrations in streamwater collected at all three sites during the third storm were <15 ng/L.

Sulfometuron methyl and metsulfuron methyl were not detected in any sample analyzed as part of this study. In addition, dissolved imazapyr was not measured at concentrations greater than 0.4 µg/L in any sample collected during the first two storm events, and there was no evidence of an imazapyr pulse during either storm event. Based on these results, no samples from the third storm event (or any subsequent storm event) were analyzed to determine concentrations of these herbicides.

Dissolved AMPA and Glyphosate in Streamwater During Fifth Storm Event After Application

Results from analysis of samples collected during the first three storm events showed that dissolved glyphosate was <20 ng/L at all three sampling sites by the third storm event and that dissolved AMPA was, effectively, indistinguishable from background in all three storm events. Likewise, even though some samples collected during the first two storm events returned imazapyr detects from NCASI's analysis, none of these detections were at concentrations high enough to be free of high bias attributable to background interference, and none exceeded the ICAL LCL. In addition, on a storm- and site-specific basis, none of these data showed any evidence for a pulse of dissolved imazapyr. Thus, overall, results from the first three storm events indicate that glyphosate, AMPA, and imazapyr were at background levels by the third storm event at the latest. This, coupled with the fact that sulfometuron methyl and metsulfuron methyl were not detected above background in any sample, suggested that analysis of samples collected from subsequent storm events would serve no purpose. However, based on the NBL stage data shown in Figure G2, the fifth storm event following application was the largest event to manifest during this study, so some of these samples were analyzed for AMPA and glyphosate only.

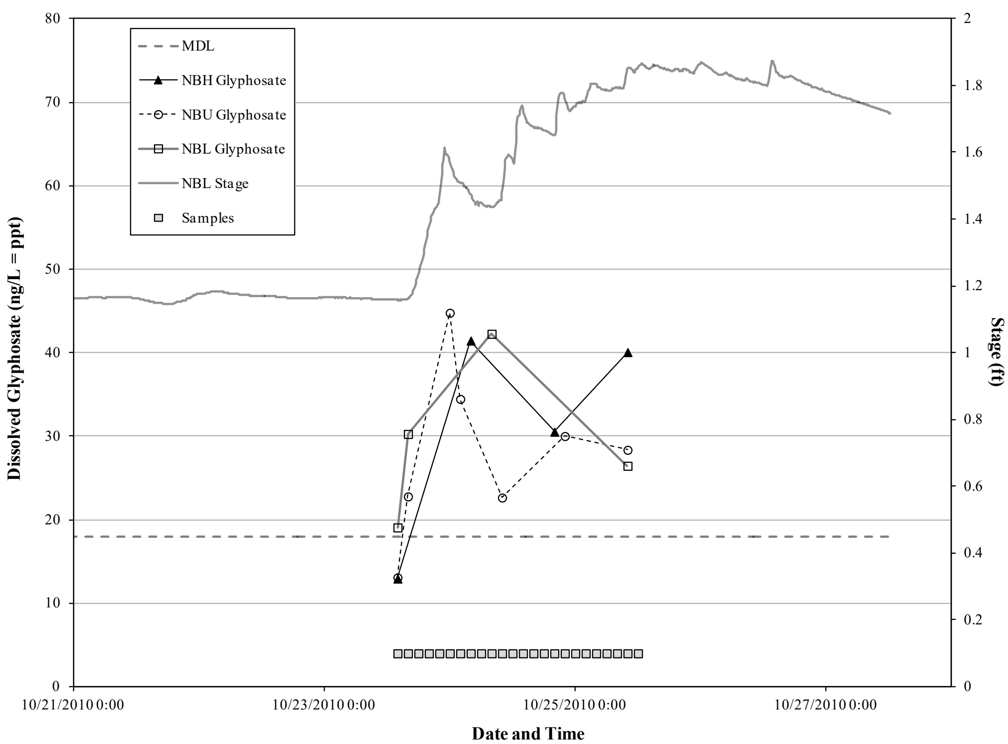

Figure G9. Dissolved Glyphosate at NBH, NBU, and NBL During Fifth Storm Event After Application of Herbicides (all concentrations plotted regardless of MDL)

The dissolved glyphosate results shown in Figure G9 are similar to those from the second (Figure G6; NBU and NBL only) and third (Figure G8; all three sites) storm events in that there was no clear pulse in dissolved glyphosate at any site, and all concentrations were low enough to be affected (i.e., biased) by background. Thus, these concentrations probably reflect background interference more than the presence of dissolved glyphosate. This is supported by the result from the single LC/MS-MS analysis performed on any of these samples, which returned a nondetect (<20 ng/L) for the sample collected 2 hours after the sample showing the highest concentration (41 ng/L) at NBH in Figure G9. Altogether, these results support concluding that dissolved glyphosate was <20 ng/L in all these samples.

Results for dissolved AMPA in these samples were also similar to those from analysis of samples collected during the earlier storm events. Measured dissolved AMPA concentrations ranged from <4 to 6 ng/L and showed no evidence of a pulse. Thus, the most defensible interpretation of these results is that dissolved AMPA was <15 ng/L in all samples collected during this storm event.

AMPA and Glyphosate on Suspended Sediments

The LCL of the calibration used to quantify AMPA and glyphosate on suspended sediments (SS) was 1.2 ng/mL (a.e.) in an extract, regardless of the mass of SS actually extracted. That is, the calibration LCL corresponds to different concentrations on solids but is constant when expressed in terms of sample volume if 80 mL of sample was filtered. The only caveat to this is the requirement that the total mass of SS extracted not exceed 10 mg/L; thus, SS in an 80-mL sample should be ≤125 mg/L. As noted, SS concentrations were not measured in samples. However, it was the assessment of all involved that SS was generally low (<125 mg/L). As a consequence, only a handful of SS analyses were performed, and in all cases, a full 80 mL of sample was filtered.

The results of these analyses showed that regardless of the true SS concentration in each sample, the mass of both AMPA and glyphosate on SS contributed to the total mass found in samples was *de minimis*. As an example, the single highest dissolved glyphosate concentration found in any sample by NCASI's analysis was 149 ng/L (the corresponding LC/MS-MS result was 115 ng/L). When the unfiltered (whole) split of this sample was filtered, the filtrate and SS fractions analyzed separately, and the results summed, the total glyphosate concentration was 155 ng/L (NCASI's analysis). Thus, results suggest that glyphosate on SS was equivalent to ≈6 ng/L (or ≈4% of the total mass of glyphosate in this sample). However, this almost certainly overstates the contribution of SS to total glyphosate because the background interference affecting glyphosate in extracts obtained from filtrates also manifested in SS extracts. This means that even when there is no glyphosate on sample SS, an associated measured total concentration is expected to be ≈13 ng/L higher than a dissolved concentration solely as a consequence of the background interference.

In no case was the mass of glyphosate found on SS >13 ng/L. Thus, regardless of the apparent relative (percent) increase in glyphosate resulting from adding glyphosate on SS to dissolved glyphosate, the increase can be attributed to background interference in the SS measurement.

The ultimate interpretation of these results is that there was no measurable glyphosate on sample SS. Obviously, the low level of SS in these samples may have been the primary factor contributing to this outcome.

Analysis of AMPA results follows the discussion of glyphosate; that is, any AMPA on sample SS can be attributed to background interference acting on the SS measurement. Thus, the final interpretation is that there was no measurable AMPA on sample SS.

Summary

Dissolved AMPA and Glyphosate Concentrations

Dissolved AMPA and Glyphosate: Streamwater During Herbicide Application

As shown in Figure G3, there was a clear pulse of dissolved glyphosate at NBH during herbicide application. This pulse showed the highest concentration in the first sample collected after application was initiated and then tailed off over approximately 6 hours. That is, the pulse persisted for no more than 6 hours, and the "peak" persisted for only 2-3 hours. Glyphosate in this pulse "peaked" at 62 ng/L without background subtraction, or 42 ng/L after subtracting the event- and site-specific background signal. No glyphosate pulse was detected in samples collected at NBL, and no samples were collected at NBU during application (autosampler malfunction). As might be expected, AMPA was not detected in any sample collected during the application.

Dissolved AMPA and Glyphosate: Streamwater Collected During Storm Events

Results support these statements regarding dissolved glyphosate in streamwater collected during storm events:

- During the first two storm events after application (8 and 10 DAT), dissolved glyphosate manifested in streamwater as discrete pulses with a duration of 8-10 hours.
- No pulses in dissolved glyphosate were observed in later storm events.
- The maximum concentration observed during storm events decreased from NBH to NBU to NBL (i.e., decreased going downstream from the application site).
- The maximum concentration observed at each site decreased with each storm event.
- Dissolved glyphosate in streamwater collected at NBL during the first storm event (8 DAT) was <20 ng/L[2] (i.e., no pulse of dissolved glyphosate was observed at NBL during any storm event).
- Dissolved glyphosate was <20 ng/L at NBU by the second storm event (10 DAT).
- Dissolved glyphosate was <20 ng/L at NBH by the third storm event (24 DAT).
- The highest dissolved glyphosate concentration found in any sample was 115 ng/L at NBU during the first storm event (8 DAT); this concentration persisted for no more than 2-3 hours.

The last of these statements should be qualified by noting that no pulse in dissolved glyphosate was observed at NBH during the first storm event. Based on the totality of the results, a pulse at NBH was expected, and it would also be expected that the maximum concentration in that pulse would be higher than that seen at NBU during the same storm event. Thus, the 115 ng/L observed at NBU during the first storm event following application of herbicide may not have been as high as would have been found at NBH during the same storm event.

Measured dissolved AMPA was <12 ng/L in all baseflow and storm event samples, and dissolved AMPA in streamwater collected during storm events was generally at concentrations equivalent to those found in baseflow. In no case was a clear pulse of dissolved AMPA observed during a storm event. Taken together, these factors suggest that all measurements reflected variability in the background interferent known to be present in all samples rather than the actual presence of AMPA. The measured

[2] Based on results obtained from LC/MS-MS confirmation analysis.

concentrations certainly carry high bias due to this background, and all were less than the 15 ng/L ICAL LCL for AMPA. Thus, the most defensible conclusion that can be drawn from these results is that dissolved AMPA was <15 ng/L in all streamwater samples collected during storm events.

Dissolved AMPA and Glyphosate: Streamwater Collected During Postapplication Baseflow Conditions

Results from streamwater collected during baseflow conditions showed dissolved glyphosate at ≈25 ng/L (based on results from the LC/MS-MS confirmation analysis) at all three sites 3 DAT. The next baseflow sample, collected 19 DAT, showed <20 ng/L dissolved glyphosate at all three sites, and all subsequent baseflow samples also showed <20 ng/L. Thus, results show that baseflow immediately following the application contained ≈25 ng/L of dissolved glyphosate for a short period (days to perhaps 2 weeks) and that concentrations dropped to <20 ng/L by 19 DAT.

Results suggested that there was 6-7 ng/L dissolved AMPA in baseflow at all three sites 3 DAT, and that concentrations dropped to <4 ng/L in baseflow at NBH and NBU by the next baseflow sampling (19 DAT) but remained at these approximate levels throughout the study period at NBL. (The last baseflow sample analyzed for determination of AMPA and glyphosate was collected 103 DAT.) However, these measured concentrations are all in the range of concentrations measured in various preapplication (background) samples, which gave concentrations as high as 7 ng/L (as AMPA), and all are below the ICAL LCL for AMPA (15 ng/L). Thus, the most defensible conclusion is that dissolved AMPA was <15 ng/L in all baseflow samples.

AMPA and Glyphosate on Suspended Sediments

Glyphosate and AMPA were not found on sample SS at concentrations greater than the background interferent known to be present in SS extracts. Combining this with the observation that all samples contained little to no SS indicates that export of glyphosate and AMPA on SS was *de minimis*.

Dissolved Imazapyr, Sulfometuron Methyl, and Metsulfuron Methyl Concentrations

Dissolved Imazapyr, Sulfometuron Methyl, and Metsulfuron Methyl: Streamwater Collected During Application of Herbicides

Due to a malfunction of the autosampler, no samples were collected at NBH during application of herbicides, and because of the low concentrations found in samples collected at NBU, none of the samples collected at NBL were analyzed.

Samples collected at NBU during the application gave imazapyr measurements ranging from <0.2 (i.e., nondetect) to 0.3 µg/L. However, no clear pulse of imazapyr was observed. Concentrations at these levels are subject to bias due to background interference and are below the ICAL LCL for imazapyr (0.6 µg/L). Although it cannot be proven, this suggests that what was being measured in these samples was background, not imazapyr. Because of the uncertainties concerning sample-to-sample variability in the background signal and the resulting uncertainties regarding detection, the most defensible conclusion to be drawn from these results is that dissolved imazapyr was <0.6 µg/L in NBU baseflow samples collected during the application of herbicides.

Sulfometuron methyl and metsulfuron methyl were not detected in any sample collected during this study, including those collected at NBU during application of herbicides. Thus, all that can be said about these herbicides in samples collected during the application is that concentrations never exceeded MDLs, which were 0.5 µg/L and 1.0 µg/L for sulfometuron methyl and metsulfuron methyl, respectively.

Dissolved Imazapyr, Sulfometuron Methyl, and Metsulfuron Methyl: Streamwater Collected During Storm Events

Although measured imazapyr exceeded the MDL (0.2 µg/L) in a handful of storm event samples, the highest concentration detected was 0.4 µg/L, indicating that all measured imazapyr concentrations were low enough to be biased high due to the effect of background interference and were less than the associated ICAL LCL, which was 0.6 µg/L. In addition, in no case was there any evidence for a pulse of imazapyr during a storm event. Taken together, these factors suggest that all results for imazapyr in samples collected during storm events reflected variability in the background interferent rather than the presence of imazapyr. However, this cannot be proven. Thus, the most defensible conclusion that can be drawn from these results is that dissolved imazapyr was <0.6 µg/L in all samples collected during postapplication storm events.

Sulfometuron methyl and metsulfuron methyl were not detected in any sample collected during this study. Thus, all that can be said about these herbicides in samples collected during storm events is that concentrations never exceeded MDLs, which were 0.5 µg/L and 1.0 µg/L for sulfometuron methyl and metsulfuron methyl, respectively.

Dissolved Imazapyr, Sulfometuron Methyl, and Metsulfuron Methyl: Streamwater Collected During Postapplication Baseflow Conditions

Imazapyr was not detected (i.e., <0.2 µg/L) in most baseflow samples collected after application of herbicides,and exceeded the MDL in only one baseflow sample collected at NBH and one collected at NBU. As discussed earlier, concentrations at these levels are subject to bias due to background interference and are below the ICAL LCL for imazapyr (0.6 µg/L). Although it cannot be proven, this suggests that what was being measured in these samples was background, not imazapyr. Ultimately, because of the uncertainties concerning sample-to-sample variability in the background signal and the resulting uncertainties regarding detection, the most defensible conclusion to be drawn from these results is that dissolved imazapyr was <0.6 µg/L in all postapplication baseflow samples.

Neither sulfometuron methyl nor metsulfuron methyl were detected in any sample collected during this study. Thus, all that can be said about these herbicides in postapplication baseflow samples is that concentrations never exceeded MDLs, which were 0.5 µg/L and 1.0 µg/L for sulfometuron methyl and metsulfuron methyl, respectively.

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