2012 BOARDMAN AND RIVER FOREST CREEKS BENTHIC MACROINVERTEBRATE ASSESSMENT FOR THE OAK LODGE SANITARY DISTRICT, CLACKAMAS COUNTY, OREGON

MICHAEL B. COLE, PH.D. AND NICK HAXTON, M.S.

PREPARED FOR

OAK LODGE SANITARY DISTRICT
OAK GROVE, OREGON

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FOREST GROVE, OREGON

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FINAL REPORT

Prepared for

Karen Streeter

Oak Lodge Sanitary District

14611 SE River Road

Oak Grove, OR 97267-1198

Prepared by

Michael B. Cole, Ph.D. and Nick Haxton, M.S.

ABR, Inc.—Environmental Research & Services

P.O. Box 249

Forest Grove, OR 97116

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EXECUTIVE SUMMARY

- As Portland, Oregon's popularity and population increase, so do the demands on regional and local resource managers to maintain and improve aquatic resource conditions, functions and values. The Oak Lodge Sanitary District (OLSD) is one of a number of agencies responsible for wastewater and stormwater management in the region. In an effort to better understand the effects of these management activities on watershed health and the status of aquatic resources in the district, OLSD performed an assessment of macroinvertebrate communities in Boardman and River Forest creeks in 2012. The information and data derived from these monitoring and assessment efforts are used to help determine the success of water resource management efforts and inform future work.
- Macroinvertebrate communities, physical habitat, and water chemistry were sampled from 3 survey reaches on 26 and 27 September, 2012. Habitat surveys were performed in the reaches following a modified Rapid Stream Assessment Technique (RSAT) which consisted of data collection from individual channel habitat units, three channel cross sections, and the adjacent riparian zone. Basic water chemistry was measured at each reach at the time of macroinvertebrate sampling. Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams. A series of metrics that each describe some macroinvertebrate community attribute was used to analyze the macroinvertebrate data. DEQ's Marine Western Coastal Forest Predictive Model was also used to analyze the data.
- All three stream reaches included in this study were characterized as low-gradient reaches, each with a <1% channel gradient. At the time of sampling each reach, little water velocity or discernible moving water was observed. Each reach supported some emergent vegetation and/or free-floating duckweed. Wetted channel widths ranged from 2.6 m to 4.8 m, and bankfull width ranged from 3.7 m in River Forest Creek to 12.6 m Boardman Creek in Stringfield Park. These reaches were all heavily dominated by glide habitats (mean 94%), and fine substrates (mean 93%). Riparian buffer zones were generally narrow across the 3 reaches, ranging from 10 m wide at upper Boardman Creek and River Forest Creek to 18 m wide at Boardman Creek in Stringfield Park. Among water chemistry parameters sampled at each reach, dissolved oxygen measurements were most notable. Dissolved oxygen values measured in early to late afternoon (when values would be expected to be close to their diel maximum) ranged from 1.27 mg/L in upper Boardman Creek to 2.98 mg/L in River Forest Creek.
- Macroinvertebrate samples collected from the 3 study reaches were characterized as supporting no mayfly, stonefly, or caddisfly taxa (EPTs); a high proportion of organisms tolerant to disturbance and degraded water quality; and high Hilsenhoff Biotic Index scores. These samples were each dominated by Oligochaeta (segmented worms), regarded as one of the most tolerant groups of aquatic macroinvertebrates. Total taxa richness was low, ranging from 9 taxa in the River Forest Creek sample to 14 taxa in the Boardman Creek sample.
- MWCF O/E scores were also low and ranged from 0.145 in River Forest Creek to 0.242 from upper Boardman Creek. The average O/E score was also calculated for 6 geomorphically similar reaches in a 2011 Clackamas Water & Environment Services study for comparison: O/E scores averaged 0.390 in the 2011 study versus 0.194 in the OLSD study. In other words, twice as many taxa predicted to occur in the stream reaches occurred in the WES study reaches than in the OLSD study reaches, further suggesting significant disturbance to the OLSD macroinvertebrate communities.
- The macroinvertebrate communities of Boardman and River Forest creeks, like those in many urban and suburban streams, also stand to benefit from improved stormwater management. One of the primary goals of the

OLSD macroinvertebrate monitoring program is to assess the effects of stormwater runoff on the biology of area creeks. These data serve as a baseline against which to evaluate improvements to the macroinvertebrate community in response to the OLSD's efforts to curtail stormwater runoff into receiving waters and improve the quality of stormwater runoff entering into local creeks. Continued monitoring of these resources should serve as an effective measure of the long-term success of these efforts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

As Portland, Oregon's popularity and population increase, so do the demands on regional and local resource managers to maintain and improve aquatic resource conditions, functions and values. The Oak Lodge Sanitary District (OLSD) is one of a number of agencies responsible for wastewater and stormwater management in the region, and administers surface water management programs within its geographic boundaries. In an effort to better understand the effects of these management activities on watershed health and the status of aquatic resources in the district, OLSD performed an assessment of macroinvertebrate communities in several streams within their jurisdiction in fall 2012. The information and data derived from these monitoring and assessment efforts are used to help determine the success of water resource management efforts and inform future work. This report provides a detailed description of the methods, results, and interpretation of these assessments conducted in 2012.

SURVEY AREA

The district is comprised of four basins: Boardman, River Forest, Rinearson and Courtney Springs. Together, these basins comprise approximately 3600 acres of watersheds that drain to the Willamette River. The area is largely unincorporated Clackamas County, commonly known as the Oak Grove and Jennings Lodge communities. The cities of Milwaukie, Clackamas and Gladstone border this area.

The area is largely developed by a range of land uses. Between the Willamette River and the McLoughlin Boulevard corridor, land use is primarily single family residential. The McLoughlin Boulevard corridor is primarily commercial uses, and east of McLoughlin to the Oatfield Ridge is single family residential and multi-family residential. Very little land remains undeveloped, with most development having occurred over a long history starting in the 1930's. The McLoughlin Boulevard Corridor or commercial development began in the 1960's and 1970's. Currently, several of the commercial business sites are vacant because of poor economic conditions.

The landform of the district primarily drains westward, from the Oatfield Ridge down to the Willamette River. In the southern part of the district, a short plateau occurs, which is the location where a large wetland complex developed.

METHODS

SURVEY REACHES

Three reaches were sampled within OLSD study area in 2012 (Table 1). Boardman Creek was sampled at two locations: within Stringfield Park and at Boardman Avenue. The Stringfield Park location recently underwent restoration activities to reestablish the riparian zone within the portion of the channel reach that is within the park. This site was selected because it is in the vicinity of where water quality samples had been previously collected, because adequate water was present during the late summer sampling timing, and because access to this property is cleared through

Table 1. Stream reaches sampled for macroinvertebrates, physical habitat, and water chemistry in the Oak Lodge Sanitary District, Oregon, fall 2012.

Macroinvertebrate Site ID	Stream	Location Description	Latitude	Longitude
RFCREEK	River Forest Creek	Risley Park	45.40751	-122.64002
BOCREEK	Boardman Creek	Stringfield Park	45.39876	-122.62534
UBOCREEK	Boardman Creek	Boardman Ave	45.39510	-122.61854

an agreement that OSLD has with the North Clackamas Parks and Recreation District. Boardman Creek at Boardman Avenue was selected because of its location in the watershed at the intersection of a drainage ditch (with ongoing water quality issues) and the channel. Additionally, this site offered access through its ownership by Clackamas County, and because water was present during the time of fall sampling.

River Forest Creek was sampled within Risley Park. Similar to Stringfield Park, this site has recently undergone the first phase of riparian restoration, and an agreement that OLSD has with the Parks District offers property access for sampling. We are hoping to establish a baseline of conditions within these two parks that can be measured over the long term as the riparian vegetation becomes re-established.

MACROINVERTEBRATE ASSESSMENT

Macroinvertebrate communities, physical habitat, and water chemistry were sampled from the 3 survey reaches on 26 and 27 September, 2012. First, each survey reach was marked and the reach length was measured. Each sample reach measured 20 times the average wetted width or 75-m, whichever length was greater. Waypoints were acquired for the start and end of each reach using a GPS unit and the reach length was measured.

INSTREAM PHYSICAL HABITAT AND RIPARIAN ASSESSMENT

Habitat surveys were performed in the reaches following a modified Rapid Stream Assessment Technique (RSAT) which consisted of data collection from individual channel habitat units, three channel cross sections, and the adjacent riparian zone (Table 2). First, the valley type within each survey reach was broadly classified as U-type, V-type, ponded, or floodplain. A plan view of the reach was sketched as the survey was performed. The physical habitat data were then collected using the following procedures:

Habitat Units Survey

The number, length, width, maximum water depth, and gradient of pools, glides, riffles, and rapids were recorded in each reach. The following definitions were adapted from the Oregon Department of Fish and Wildlife's (ODFW) Methods for Stream Habitat Surveys (2002) and Armantrout (1998) and used for this study:

> *Pool*: Water surface slope is usually zero. Pools are normally deeper and wider than aquatic habitats immediately upstream and downstream.
>
> *Glide*: There is a general lack of consensus of the definition of glides (Hawkins et al. 1993). For the purposes of this study, a glide was defined as an area with generally uniform depth and flow with no surface turbulence. Glides have a low-gradient water surface profile of 0–1% slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Glides are generally deeper than riffles with few major flow obstructions.
>
> *Riffle*: Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Riffles generally have a broad, uniform cross section and a low-to-moderate water surface gradient, usually 0.5–2.0% slope and rarely up to 6%.
>
> *Rapids*: Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders. Rapids often contain exposed substrate features composed of individual bedrock or boulders, boulder clusters, and partial bars. Rapids are moderately high gradient habitat, usually 2.0–4.0% slope and occasionally 7.0–8.0%. Rapids also include swift, turbulent, "sheeting" flow over smooth bedrock.

The following attributes were then measured or visually estimated in each channel unit. Substrate composition was visually estimated in each unit using substrate size classes adapted from the United States Environmental Protection Agency's (USEPA) Environmental Monitoring & Assessment Protocols (EMAP) protocols for wadeable streams (USEPA 2000). Percent actively eroding banks and percent undercut banks (both banks, combined) were each visually estimated.

Table 2. Environmental parameters measured in the field to characterize stream reaches in the Oak Lodge Sanitary District, Oregon, fall 2012.

Variable	Quantitative or Categorical	Visual Estimate or Measured Variable
Reach length (m)	Q	M
Valley type	C	V
Channel unit gradient (%)	Q	M
Wetted width (m)	Q	M
Bankfull width (m)	Q	M
Bankfull height (m)	Q	M
Mean water depth (cm)	Q	M
Rapids (% of reach length)	Q	M
Riffles (% of reach length)	Q	M
Glides (% of reach length)	Q	M
Pools (% of reach length)	Q	M
Substrate composition	Q	M
Substrate embeddedness (%)	Q	M
Large wood tally	Q	M
Overhead canopy cover (%)	Q	M
Reach embeddedness (%)	Q	V
Eroding banks (%)	Q	V
Undercut banks (%)	Q	V
Mean riparian buffer width (m)	Q	V
Riparian zone tree cover (%)	Q	V
Non-native riparian vegetation cover (%)	Q	V
Dominant adjacent land use	C	V
Water temperature (°C)	Q	M
pH (pH units)	Q	M
Specific conductance (µS/cm)	Q	M
Dissolved oxygen (mg/L)	Q	M

Water surface slope of each unit was measured with a clinometer. Additionally, all woody debris measuring at least 15 cm in diameter and 2 m in length was tallied for each unit and the configuration, type, location, and size of root wads and pieces of wood were noted. Overhead cover was measured with a spherical densiometer in four directions (upstream, downstream, right, and left) from the center of the stream at evenly spaced intervals along the length of the reach. Habitat features such as beaver activity, culverts, and potential fish passage barriers were noted by habitat unit.

Cross-section Surveys

Channel dimensions were measured at three transects occurring within each sample reach. The three habitat units were selected according to the following guidelines:

1. Three separate riffles were sampled if three or more riffles occurred in the reach.
2. If two riffles occurred in the reach, both riffles and a representative glide or pool (least preferred) were sampled. If riffles were of sufficient length (i.e. 10% of the reach length) then more than one set of cross-section measurements were made

in the riffle to ensure that all measurements were taken from this habitat type.

3. If only one riffle occurred within the reach, two additional units that represented channel dimensions and substrate composition were sampled. If the riffle was longer than 20 m, then all three sets of measurements were taken from the riffle.
4. If no riffles occurred in the reach, three units that were representative of the channel dimensions and substrate composition occurring within the reach were sampled.

At each of the three channel cross sections, wetted width (WW), bankfull width (BFW), maximum bankfull height (BFHmax), the bankfull height at 25%, 50%, and 75% across the distance of the bankfull channel, and the flood-prone width (FPW) were measured with a tape measure and survey rod. From these channel-dimension data, width-to-depth and channel-entrenchment ratios were later calculated. Water depths were recorded at 10%, 30%, 50%, 70%, and 90% across the width of the wetted channel. Maximum bank height (left and right) and bank angles were visually estimated.

Pebble counts were performed in riffles when they represented an adequate amount of the stream channel area to allow measurement of at least 100 substrate particles along transects. If riffles occupied less than 10% of the total habitat area in the reach (e.g., if macroinvertebrate samples were collected from glides), then pebble counts occurred in glides. Pebble counts were performed using the "heel-to-toe" method, starting at the bankfull edge on one side of the channel and walking heel-to-toe to the other edge (USEPA 2000). With each step, the surveyor looked away and touched the streambed at the tip of their toe. The size class and embeddedness of each piece of streambed substrate was estimated until at least 100 particles were counted.

Riparian Surveys

Adjacent riparian conditions were characterized beyond the left and right banks separately and according to a number of attributes. The dominant plant community type(s) (riparian forest, willow shrub-scrub, upland forest, etc.) occurring in the riparian zone to the edge of human-dominated activity was classified and recorded and the approximate width of each of these community types was visually estimated. The percent vegetative cover of the canopy layer (>5 m high), shrub layer (0.5 to 5 m high), and groundcover layer (<0.5 m high) was estimated, as well as the percent cover of invasive or non-native species as a single estimate across all three vegetative layers. The dominant adjacent land use outside of the vegetated riparian buffer was noted, and then a cross-sectional diagram of the riparian zone was sketched.

WATER CHEMISTRY SAMPLING

Water temperature (°C), dissolved oxygen saturation (percent), dissolved oxygen concentration (mg/L), conductivity (µS/cm), and specific conductance (µS/cm) were measured at each reach at the time of macroinvertebrate sampling. Water temperature, dissolved oxygen, conductivity, and specific conductance were measured in situ with a multi-parameter YSI Model 85 water chemistry meter. Specific conductance is conductivity normalized to 25°C, thereby allowing more direct comparison of conductivity between water bodies or within a particular waterbody at different times.

MACROINVERTEBRATE COMMUNITY ASSESSMENT

Field Sampling

Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams (DEQ 2003). An 8-kick composite sample was collected from riffles in reaches that had sufficient riffle habitat; glides were sampled reaches that lacked riffle habitat. Instream sampling points were selected to apportion the eight kick samples among as many as four habitat units. Macroinvertebrates were collected with a D-frame kicknet (30 cm wide, 500 µm mesh opening) from a 30 x 30 cm (1 x 1 ft) area at each sampling point. Larger pieces of substrate, when encountered, were first hand-washed inside the net, and then placed

outside of the sampled area. Then the area was thoroughly disturbed by hand (or by foot in deeper water) to a depth of ~10 cm.

The eight samples from the reach were composited and carefully washed through a 500 µm sieve to strain fine sediment and hand remove larger substrate and leaves after inspection for clinging macroinvertebrates. The composite sample was placed into one or more 1-L polyethylene wide-mouth bottles, labeled, and preserved with 80% denatured ethanol for later sorting and identification at the laboratory.

Sample Sorting and Macroinvertebrate Identification

Samples were sorted to remove a 500-organism subsample from each preserved sample following the procedures described in the DEQ Level 3 protocols (Water Quality Interagency Workgroup [WQIW], 1999) and using a Caton gridded tray, as described by Caton (1991). Contents of the sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were transferred to a Petri dish, which was examined under a dissecting microscope at 7–10X magnification to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted.

Following sample sorting, all macro-invertebrates were identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments (WQIW 1999). In 2011, chironomids (Family: Chironomidae) collected in glide samples were identified to species. Aquatic insects were keyed using Merritt, Cummins, and Berg (2008), Wiggins (1995), Stewart and Stark (2002), and a number of regional and taxa-specific keys.

Data Analysis

Existing tools employed by Oregon DEQ for analysis of macroinvertebrate data in western Oregon have been developed from, and therefore are only appropriate for, assessment of assemblages collected from coarse substrates in riffle habitats. However, riffle habitat supporting coarse substrate is infrequent or absent from many of the low-gradient, fine-sediment-dominated streams of the Willamette Valley floor. Therefore, assessing macroinvertebrate communities of valley floor streams requires sampling from other habitats such as sand and silt-dominated glides. These habitats do not support the same biological potential with respect to species richness as do riffle habitats because a number of characteristics known to influence macroinvertebrate community composition such as stream substrate, water velocity, and abundance and types of organic materials naturally differ between these habitats. Consequently, use of existing bioassessment tools and their attendant condition thresholds is inappropriate for assessing the condition of benthic communities in these low-gradient streams. Analysis of glide samples collected from these streams with existing bioassessment tools would result in artificially lower index scores and corresponding impairment classifications. Consequently, analysis of macroinvertebrate data from this study was performed with modifications to standard assessment tools—community metric analysis and the MWCF Predictive Model—as described below.

Community Metric Calcuations

Community metric analysis (also known as multimetric analysis) employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown to be associated with one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. The DEQ has developed and currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999). For this study, we used 9 metrics, some of which differ from those used for analysis of riffle samples, to evaluate macroinvertebrate community conditions from these three

low-gradient reaches (Table 3). Metrics that previously have been shown to effectively characterize macroinvertebrate communities in low-gradient streams (Cole 2002) and those that provided a range of values among glide samples were selected for inclusion in the set; metrics that showed little variation among low-gradient reaches, such as sensitive taxa richness, were excluded from the data set. The DEQ taxa attribute coding system was used to assign these classifications to taxa in the data set (DEQ, unpublished information).

When used with riffle samples from higher-gradient streams, the raw metric values are converted to standardized scores using DEQ scoring criteria. The standardized scores are then summed to produce a multimetric score ranging between 10 and 50. Reaches are then assigned a level of impairment based on these total scores. Because the scoring criteria and impairment class thresholds are inappropriate for the stream type sampled in this study, the raw metric values themselves are used to assess macroinvertebrate community condition.

PREDATOR Analysis

PREDATOR is a predictive model that evaluates macroinvertebrate community conditions based on a comparison of observed (O) to expected (E) taxa (Hawkins et al. 2000, Hubler 2008). The observed taxa are those that occurred at the reach, whereas the expected taxa are those commonly occurring (>50% probability of occurrence) at reference reaches. The expected taxa, therefore, are taxa that are predicted to occur within a reach in the absence of disturbance Biological condition is determined by comparing the O/E score to the distribution of reference reach O/E scores. As is the case with the multimetric index, the PREDATOR model for western Oregon [the Marine Western Coastal Forest (MWCF) model] has been developed only from riffle samples collected from higher-gradient streams. Therefore, using the MWCF biological condition thresholds (Hubler 2008), to determine level of disturbance to the macroinvertebrate community is inappropriate. As such, MWCF model scores were calculated for each sample collected in this study, but condition classes were not assigned. Rather, the scores can be used as a further measure of relative condition across sites and over time at each site.

Table 3. Metric set used to assess condition of macroinvertebrate communities sampled from glides in the Oak Lodge Sanitary District, Oregon, fall 2012.

Metric
Taxa richness
EPT taxa richness
% Dominant (1 taxon)
Modified HBI
% Sediment tolerant taxa
% Tolerant taxa
% Chironomidae
% Mollusca
% Oligochaeta

RESULTS

INSTREAM PHYSICAL HABITAT AND ASSOCIATED ENVIRONMENTAL CONDITIONS

All three stream reaches included in this study were characterized as low-gradient reaches, each with a <1% channel gradient (Table 4). At the time of sampling each reach, little water velocity or discernible moving water was observed. Each reach supported some emergent vegetation and/or free-floating duckweed. Wetted channel widths ranged from 2.6 m to 4.8 m, and bankfull width ranged from 3.7 m in River Forest Creek to 12.6 m Boardman Creek in Stringfield Park. These reaches were all heavily dominated by glide habitats (mean 94%), and fine substrates (mean 93%). Gravels, cobbles, and other coarse inorganic substrates were lacking in each reach; only hardpan or small pieces of wood accounted for any measured substrate aside from fine materials. Substrate embeddedness (as estimated from pebble counts) in all three reaches was high (mean 95.7%). Stream bank erosion was highest in the Boardman Creek reach (BOCREEK), with 50% eroding banks. Bank erosion was lower in both the upper Boardman Creek and River Forest Creek reaches, with 10% and 13% eroding banks, respectively.

Table 4. Environmental conditions of stream reaches sampled in the Oak Lodge Sanitary District, Oregon, fall 2012.

Environmental parameter	Mean	SD	Min	Max
Channel slope (%)	1.0	0.0	1.0	1.0
Wetted width (m)	3.7	1.1	2.6	4.8
Bankfull width (m)	8.4	4.5	3.7	12.6
Percent pools	0.0	0.0	0.0	0.0
Percent glides/runs	94.2	10.0	82.7	100.0
Percent riffles	5.8	10.0	0.0	17.3
Percent other	0.0	0.0	0.0	0.0
Percent coarse substrate	0.0	0.0	0.0	0.0
Percent fine substrate	93.1	8.1	84.2	100.0
Substrate embeddedness	95.7	7.5	87.1	100.0
Eroding banks	24	22	10	50
Undercut banks	23	36	0	65
Large wood tally (#/m)	0.01	0.01	0.00	0.01
Overhead cover (%)	40	23	14	54
Mean riparian width (m)	13	4	10	18
Riparian zone tree cover (%)	23	23	10	50
Riparian zone non-native Veg. Cover (%)	34	18	15	50
Dissolved oxygen (%)	24.1	9.5	13.1	30.0
Dissolved oxygen (mg/L)	2.37	0.95	1.27	2.98
Specific conductance (µS/cm)	200.80	31.78	166.10	228.50

Riparian buffer zones were generally narrow across the 3 reaches, ranging from 10 m wide at upper Boardman Creek and River Forest Creek to 18 m wide at Boardman Creek in Stringfield Park. Tree cover was low at both upper the Boardman Creek and River Forest Park reaches (10% tree cover in each reach), but the Boardman Creek reach supported several mature trees in the immediate riparian zone, providing 50% tree cover to the reach (Table 4).

Among water chemistry parameters sampled at each reach, dissolved oxygen measurements were most notable. Dissolved oxygen values measured in early to late afternoon (when values would be expected to be close to their diel maximum) ranged from 1.27 mg/L in upper Boardman Creek to 2.98 mg/L in River Forest Creek (Table 4).

MACROINVERTEBRATE COMMUNITY CONDITIONS

Macroinvertebrate samples collected from the 3 study reaches were characterized as supporting no mayfly, stonefly, or caddisfly taxa (EPTs); a high proportion of organisms tolerant to disturbance and degraded water quality; and high HBI scores (Table 5). These samples were each dominated by Oligochaeta (segmented worms), regarded as one of the most tolerant groups of aquatic macroinvertebrates. Total taxa richness was low, ranging from 9 taxa in the River Forest Creek sample to 14 taxa in the Boardman Creek sample. Other taxa abundant in the samples included the Chironomidae (subfamily: Tanypodinae) genus, *Psectrotanypus* sp., which was common in both the Boardman Creek and upper Boardman Creek samples. Psectrotanypus is classified by DEQ as a tolerant taxon with an HBI value of 10 (the highest value assigned to organic enrichment pollution tolerance). Filter-feeding Pisidiidae clams were also among the most abundant taxa at each

Table 5. Macroinvertebrate community metrics calculated from samples collected from stream 3 reaches in the Oak Lodge Sanitary District, Oregon, fall 2012 (n= 3). Column on right side indicates average metric values calculated from 6 low-gradient streams sampled for Clackamas County Water Environment Services (WES) in 2011 for comparison with present study.

	Site ID				
Metric	RFCREEK	BOCREEK	UBOCREEK	UBOCREEK Dup	2011 WES Avg (n = 6)
Taxa Richness	9	14	8	12	27
EPT Taxa Richness	0	0	0	0	2.5
% Dominant	41	54	51	31	38
Modified HBI	7.0	7.2	6.7	7.0	6.3
% Sed.Tolerant	42	54	51	31	45
% Tolerant	46	80	62	54	51
% Chironomidae	0	23	11	21	23
% Molluska	46	14	14	6	26
% Oligochaeta	41	54	51	31	38
% CMO	88	91	76	58	87

location; this taxon also has a high HBI value of 8. Overall HBI scores ranged from 6.7 in upper Boardman Creek to 7.2 in Boardman Creek, consistently indicating a benthic community that is highly tolerant to organic enrichment pollution (Table 5).

To assist with evaluating these conditions, we calculated the mean value for each of these metrics from 6 glide samples collected in 2011 across low-gradient streams in northern Clackamas County for Clackamas Water Environment Services, hereafter referred to as WES (Lemke et al. 2012a, Lemke et al. 2012b). Comparisons with the WES data indicate highly disturbed conditions across the 3 OLSD study sites. For example, taxa richness from low-gradient, glide-dominated reaches averaged 27 in the 2011 WES study, compared to only 11 in the OLSD study. Similarly, EPT richness averaged 2.5 taxa per sample in the 2011 WES study versus 0 in the present study.

MWCF O/E scores were also low and ranged from 0.145 in River Forest Creek to 0.242 from upper Boardman Creek (Table 6). As with the metric scores, the average O/E score was calculated for the 6 reaches in the 2011 WES study for comparison: O/E scores averaged 0.390 in the WES study versus 0.194 in the OLSD study. In other words, twice as many taxa predicted to occur in the stream reaches occurred in the WES study reaches than in the OLSD study reaches, further suggesting significant disturbance to the OLSD macroinvertebrate communities.

DISCUSSION

Streams sampled in this study support degraded macroinvertebrate communities as evaluated by both the MWCF predictive model and a number of individual community metrics. All of the test reaches would have received the lowest classification of severely disturbed had impairment classes been assigned to the reaches based on O/E scores. We hesitate to assign impairment classes to these stream reaches as the MWCF predictive model was developed using data collected from higher gradient stream reaches that support macroinvertebrate communities that differ from those occurring in low gradient streams, even under natural conditions. As noted previously, glide samples were collected within the test reaches due to the lack of riffle habitat in the sample reaches. Despite the inability to assign condition classes from standardized scoring criteria (because none have been developed for

Table 6. Macroinvertebrate MWCF O/E scores calculated from samples collected from 3 stream reaches in the Oak Lodge Sanitary District, Oregon, fall 2012.

Site ID	Observed Taxa	Expected Taxa	O/E
RFCREEK	3	20.63	0.145
BOCREEK	4	20.63	0.194
UBOCREEK	5	20.64	0.242
UBOCREEK Dup	4	20.64	0.194
2011 WES Avg	8	20.64	0.390

low-gradient, valley floor streams), the exceedingly low O/E scores associated with the test reaches do indicate that macroinvertebrate community condition has been impacted by degraded physical habitat conditions and/or impaired water quality. Sampling glide habitats from other low-gradient streams in other areas of the lower Willamette River valley has produced O/E scores exceeding 0.5-0.6, while the highest O/E score was 0.242 in the present study.

The macroinvertebrate communities in the study reaches consisted almost entirely of organisms that are able to tolerate elevated sediment loads, increased water temperatures, periods of sustained high or low flows, and other perturbations. Sensitive taxa such as mayflies, stoneflies, and caddisflies were absent from samples collected from these reaches. While EPT taxa richness is generally low in these valley floor, glide-habitat dominated environments, the complete absence of these more sensitive aquatic insects clearly suggests that these systems are stressed. Environmental conditions observed and measured at the study reaches suggest that these streams are hydrologically, physically, and chemically altered. Identifying the specific cause(s) of the measured biological degradation can be challenging, but our data reveal some potential sources of stress. Specifically, dissolved oxygen concentrations were dangerously low, even in the mid-afternoon, when their concentrations should be at their highest after a day of photosynthetic activity. The low dissolved oxygen occurring in these systems will continue to significantly limit biological diversity and ability of native fish and macroinvertebrate communities to persist.

Recovery of macroinvertebrate communities is dependent on identifying and improving currently compromised stream conditions and functions. Riparian zone revegetation and protection are among the most beneficial stream restoration approaches available. Because riparian zones provide a number of important functions, including sediment and pollutant retention, shading, food sources, bank stability, and large wood inputs, streams and the biological communities they support derive many benefits from these areas.

The macroinvertebrate communities of Boardman and River Forest creeks, like those in many urban and suburban streams, also stand to benefit from improved stormwater management. One of the primary goals of the OLSD macroinvertebrate monitoring program is to assess the effects of stormwater runoff on the biology of area creeks. These data serve as a baseline against which to evaluate improvements to the macroinvertebrate community in response to the OLSD's efforts to curtail stormwater runoff into receiving waters and improve the quality of stormwater runoff entering into local creeks. Continued monitoring of these resources should serve as an effective measure of the long-term success of these efforts.

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Appendix A. Reach Assessment Summary Sheets

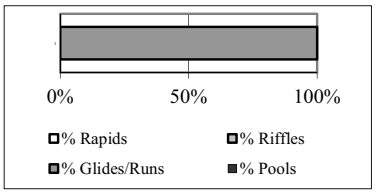
Reach Assessment Summary

Stream Name:	**upper Boardman Creek**	Site ID:	UBOCREEK
Location:	Boardman Ave.	Reach ID:	UBOCREEK
County, State:	Clackamas, Oregon	Latitude:	45.39510
Date sampled:	9/27/2012	Longitude:	-122.61854
Field Personnel:	NDH, MMA	Reach Length:	75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

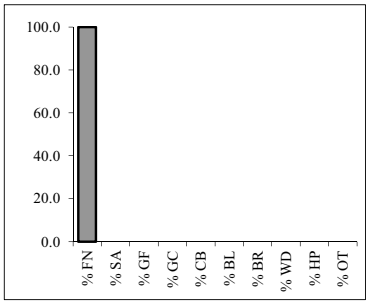
Reach Gradient (%)	1.0
Wetted Width (m)	4.8
Bankfull Width (m)	9.0
% Rapids	0.0
% Riffles	0.0
% Glides/Runs	100.0
% Pools	0.0



At survey start, looking upstream

Substrate

% Fines (FN)	100.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	0.0
% Gravel, Coarse (GC)	0.0
% Cobble (CB)	0.0
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	100.0
Large Wood Tally (pieces/m)	0.00
Eroding Banks (%)	10
Undercut Banks (%)	0



At end of survey, looking downstream

Riparian Zone Characteristics

Canopy Cover (%)	14
Riparian Buffer Width (m)	10
Riparian Zone Tree Cover (%)	10
Riparian Zone Non-Native Cover (%)	50
Dom Adjacent Land Use	Urb

Embeddedness

Canopy Cover

Upstream

Downstream

Mapped Reach Location

Chemical Characteristics

Water Temperature (°C)	18.0
Dissolved Oxygen (%)	13.1
Dissolved Oxygen (mg/L)	1.27
Time of measurement	12:42

Biological Conditions Summary

ABR Sample ID: 12-621-03/04

Sample Method: OR DEQ 8-kick composite

Habitat(s) Sampled: Glide(s)

Community Metrics (glide)

Richness	8.0
EPT Richness	0.0
% Dominant	50.7
Modified HBI	6.7
% Sed Tolerant	50.7
% Tolerant	62.1
% Chironomidae	11.0
% Molluska	13.9
% Oligochaeta	50.7
%CMO	75.6

Sample Taxa List

Taxon	Count
Oligochaeta	262
Ceratopogoninae	116
Pisidiidae	72
Psectrotanypus sp.	56
Nemata	7
Helobdella stagnalis	2
Chironomus sp.	1
Oribatei	1
Total Count	517

PREDATOR MWCF O/E Score:

Sample	O/E Score
Primary	0.242272
Duplicate	0.193818

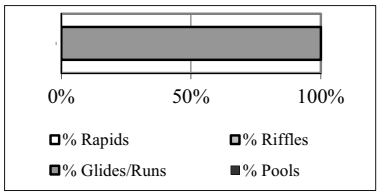
Reach Assessment Summary

Stream Name:	**Boardman Creek**	Site ID:	BOCREEK
Location:	Stringfield Park	Reach ID:	BOCREEK
County, State:	Clackamas, Oregon	Latitude:	45.39876
Date sampled:	9/26/2012	Longitude:	-122.62534
Field Personnel:	NDH, MMA	Reach Length:	75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

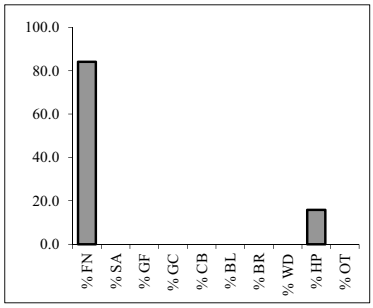
Reach Gradient (%)	1.0
Wetted Width (m)	2.6
Bankfull Width (m)	12.6
% Rapids	0.0
% Riffles	0.0
% Glides/Runs	100.0
% Pools	0.0



At survey start, looking upstream

Substrate

% Fines (FN)	84.2
% Sand (SA)	0.0
% Gravel, Fine (GF)	0.0
% Gravel, Coarse (GC)	0.0
% Cobble (CB)	0.0
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	15.8
% Other (OT)	0.0
% Embeddedness	87.1
Large Wood Tally (pieces/m)	0.01
Eroding Banks (%)	50
Undercut Banks (%)	5



At end of survey, looking downstream

Riparian Zone Characteristics

Canopy Cover (%)	53
Riparian Buffer Width (m)	18
Riparian Zone Tree Cover (%)	50
Riparian Zone Non-Native Cover (%)	15
Dom Adjacent Land Use	Urb

Embeddedness

Canopy Cover

Upstream

Mapped Reach Location

Downstream

Chemical Characteristics

Water Temperature (°C)	16.7
Dissolved Oxygen (%)	29.2
Dissolved Oxygen (mg/L)	2.85
Time of measurement	15:59

Biological Conditions Summary

ABR Sample ID: 12-621-02

Sample Method: OR DEQ 8-kick composite

Habitat(s) Sampled: Glide(s)

Community Metrics (glide)

Richness	14.0
EPT Richness	0.0
% Dominant	53.6
Modified HBI	7.2
% Sed Tolerant	53.6
% Tolerant	79.8
% Chironomidae	23.3
% Molluska	14.1
% Oligochaeta	53.6
%CMO	91.0

PREDATOR MWCF O/E Score:

Sample	O/E Score
Primary	0.193857

Sample Taxa List

Taxon	Count
Oligochaeta	281
Psectrotanypus sp.	98
Pisidiidae	67
Chironomus sp.	18
Nemata	14
Crangonyx sp.	12
Ceratopogoninae	10
Physa sp.	7
Dicrotendipes sp.	5
Helobdella stagnalis	5
Peltodytes sp.	3
Corixidae	2
Paratendipes sp.	1
Turbellaria	1
Total Count	524

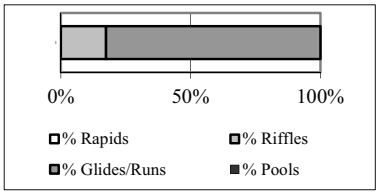
Reach Assessment Summary

Stream Name:	**River Forest Creek**	Site ID:	RFCREEK
Location:	Risley Park	Reach ID:	RFCREEK
County, State:	Clackamas, Oregon	Latitude:	45.40751
Date sampled:	9/26/2012	Longitude:	-122.64002
Field Personnel:	NDH, MMA	Reach Length:	75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

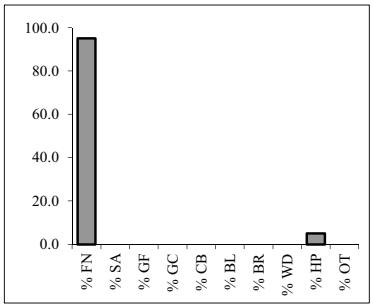
Reach Gradient (%)	1.0
Wetted Width (m)	3.8
Bankfull Width (m)	3.7
% Rapids	0.0
% Riffles	17.3
% Glides/Runs	82.7
% Pools	0.0



At survey start, looking upstream

Substrate

% Fines (FN)	95.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	0.0
% Gravel, Coarse (GC)	0.0
% Cobble (CB)	0.0
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	5.0
% Other (OT)	0.0
% Embeddedness	100.0
Large Wood Tally (pieces/m)	0.01
Eroding Banks (%)	13
Undercut Banks (%)	65



At end of survey, looking downstream

Riparian Zone Characteristics

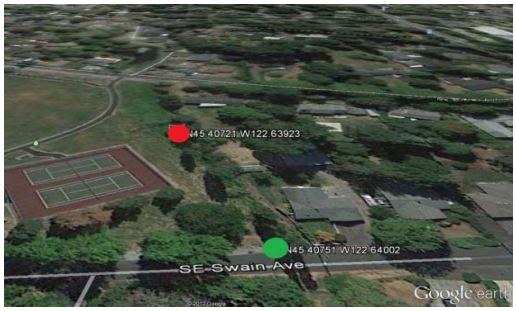
Canopy Cover (%)	54
Riparian Buffer Width (m)	10
Riparian Zone Tree Cover (%)	10
Riparian Zone Non-Native Cover (%)	38
Dom Adjacent Land Use	Urb

Embeddedness

Upstream

Mapped Reach Location

Downstream



Canopy Cover

Chemical Characteristics

Water Temperature (°C)	14.8
Dissolved Oxygen (%)	30.0
Dissolved Oxygen (mg/L)	2.98
Time of measurement	14:11

Biological Conditions Summary

ABR Sample ID: 12-621-01

Sample Method: OR DEQ 8-kick composite

Habitat(s) Sampled: Glide

Community Metrics (glide)

Richness	9.0
EPT Richness	0.0
% Dominant	41.2
Modified HBI	7.0
% Sed Tolerant	41.6
% Tolerant	45.7
% Chironomidae	0.0
% Molluska	46.4
% Oligochaeta	41.2
%CMO	87.6

Sample Taxa List

Taxon	Count
Pisidiidae	246
Oligochaeta	220
Crangonyx sp.	35
Caecidotea sp.	18
Ceratopogoninae	4
Helobdella stagnalis	4
Turbellaria	4
Menetus opercularis	2
Hyalella sp.	1
Total Count	534

PREDATOR MWCF O/E Score:

Sample	O/E Score
Primary	0.145419