Coffin Butte Landfill CUP application

REPUBLIC SERVICES

Sustainability in Action

Response to Evidence

Submitted during July 8-9 Continued Hearing

Responses

Tonnage Cap

Mark Yeager asserts that the Applicant's proposed tonnage cap will not address odor impact (Beyond Toxics Testimony Dated July 8, 2025).

The Applicant's odor model assumed 930,373 TPY of organic waste disposed at the landfill, and the County's staff is recommending that 930,373 TPY of organic waste be set as a limit which the applicant has agreed to.

However, not all material entering the landfill is organic waste, i.e. waste likely to produce odors.

Indeed around 86.4% of MSW disposed in Oregon is organic. Oregon Department of Environmental Quality, Waste Composition Study, Oregon Solid Waste Characterization and Composition Study, https://www.oregon.gov/deq/mm/Pages/Waste-Composition-Study.aspx, 2016-2017 Study, Statewide results 2016, Tab No. F16TOTMIX, *Statewide Mixed Route Trucks* attached as Exhibit 2.

In addition, other waste that has low potential to produce odor is received at the landfill, such as soil, white goods, and C&D debris.

For consistency with its odor model, the Applicant is proposing an amendment to OP-7(C), as set forth in the attached Exhibit 1. As proposed, the amended OP-7(C) would include a cap of 1.0 million tons of MSW (86.4% of which would be 864,000 tons) and 1.3 million tons of total solid waste averaged over a 12 month period.

Beginning on the date of approval of the CUP, these caps would increase annually by an amount equal to the change in CPI, except that organic waste shall not exceed the modeled 930,373 tons by more than 10% per year through 2052.

With the proposed amendment, OP-7(C) will ensure consistency with the Applicant's odor model, is easily interpreted, and will allow the facility to meet area-wide needs.

Litter

Mekenna Bradley and Mark Yeager raise concerns about windblown litter from the landfill affecting property and livestock (Mekenna Bradley Letter dated July 9, 2025) (Mark Yeager Letter dated July 9, 2025).

- The Applicant is proposing an amendment to OP-15(F), as set forth in the attached Exhibit 1. As described in this proposed condition, Republic Services will patrol the adjacent and nearby property identified in the attached Exhibit 3 on a weekly basis to ensure that any windblown litter is promptly collected and removed.
- Republic Services will perform litter collection on the adjacent and nearby property upon request by and with permission of the owner of such property
- This commitment is intended to directly address and mitigate the impacts of off-site litter.

Stormwater and Groundwater

Mark Yeager asserts that the Applicant's drainage plan directs runoff from the southernmost stormwater basin onto rural residential property (Mark Yeager Letter dated July 9, 2025). This is incorrect.

- The stormwater collected in this basin is designed to either infiltrate into the ground or evaporate.
- This basin treats stormwater through infiltration and evaporation, with overflow discharged to the wetlands north of Coffin Butte Road as intended. This design effectively manages and treats stormwater in accordance with its purpose. An overflow pipe directs excess stormwater to the detention pond near the entrance.

Beyond Toxics questions what will happen to the existing leachate ponds and suggests that they may have leaked in the past, potentially contaminating surrounding soils (Beyond Toxics Letter dated July 8, 2025).

- A leak detection layer beneath the liner system has been in place since construction, and no leaks have been indicated to date.
- The current leachate ponds will be closed in accordance with DEQ regulations, which require removal of leachate and any remaining sediment. After removal, the liners will be taken out and the underlying soil will be tested to determine whether any leakage occurred. If testing confirms the underlying soil is clean, the material may be safely reused as daily or intermediate cover.

Joel Geier submitted 12 general comments followed by three Annexes with more detailed assertions (Joel Geier Testimony dated July 8, 2025).

Geier asserts that staff has not identified specific regulatory steps to assess groundwater risks, nor contacted the Oregon Water Resources Department (Geier Annex 1, Comment 6).

- The Applicant must comply with all applicable site-specific, state, and federal landfill regulations.
- Oversight includes:
    - U.S. EPA Title 40 CFR Part 258 (Sections 258.50–258.58)
    - OAR Chapter 340, Division 40 and Division 94 (e.g., OAR 340-094-0080)
    - Site-specific Permit No. 306 and the Environmental Monitoring Plan
- Oregon DEQ—not the Oregon Water Resources Department—is the responsible regulatory agency.

Geier asserts that the Applicant did not provide calculations or parameters used in estimating dewatering impacts (Geier Annex 1, Comment 9b).

- To the contrary, the Applicant used the Dupuit solution with conservative assumptions on hydraulic properties.
- A hydrogeologic investigation will provide site-specific data to inform a groundwater model and sentry well design.
- Groundwater will be monitored and if impacts are observed, the Applicant will work with the community on mitigation.

Geier asserts that the Applicant cherry-picked from Stephen R. Hinkle & Danial J. Polette, U.S. Geological Survey, U.S. Department of the Interior, *Arsenic in Ground Water of the Willamette Basin, Oregon, Water-Resources Investigations Report 98-4205* (1999) (the "Ground Water Study") and misled the County on arsenic data (Geier Annex 1, Comment 9c). A copy of the Ground Water Study is attached as Exhibit 4.

- The Applicant used the most relevant data for conditions at Coffin Butte Landfill; arsenic is naturally present in many Oregon aquifers.
- Arsenic occurrence is due to local geology and low dissolved oxygen levels. The Ground Water Study did not measure oxygen.
- The site is underlain by Siletz River Volcanics, not the Eugene/Fisher formations. Comparisons are not appropriate.
- Arsenic-bearing soils in the Siletz formation have been documented west of Corvallis.
- Graph scales were consistent for comparison. Newer data were pending update but do not change interpretations.
- Testimony about no seepage from lined cells is accurate. Past seepage occurred at an open face of Cell 2, which occurred before the Applicant took ownership of Coffin Butte Landfill.
- Elevated chloride levels in MW-9S reflect historic sampling practices, not current conditions.
- Arsenic is monitored along with 60+ parameters. Levels in MW-9S, MW-26, and MW-27 are stable and tied to dissolved oxygen.
- A leachate plume has not been detected. Groundwater flow conditions are stable and reviewed by ODEQ annually.

Geier asserts that a single severe storm could cause catastrophic surface water and groundwater contamination if the landfill fails (Kate Harris Testimony, Dated July 8, 2025).

- The landfill is required to comply with stringent design standards under federal (40 CFR Part 258) and Oregon regulations (OAR 340-094).
- Stormwater and leachate containment systems are engineered to withstand severe weather events, including the 25-year, 24-hour storm for surface water and 100-year, 24-hour storm for leachate design.
- The landfill has never experienced a failure that resulted in contamination of offsite surface water or groundwater.

Seismic

Rana Foster asserts that the Applicant's seismic study fails to define the earthquake magnitude used in the slope stability analysis (Rana Foster Letter dated July 8, 2025).

- The slope stability analysis will incorporate the maximum probable earthquake, as defined by the USGS Seismic Probability Map.
- This approach is consistent with requirements under Title 40 CFR Part 258 and OAR 340-094, as permitted by the U.S. EPA and Oregon DEQ.

Air Quality and Odor

Ken Eklund submitted exhibits in connection with written testimony, showing an uncontextualized large methane plume originating from the Coffin Butte Landfill on April 18, 2025 (exhibit to Ken Eklund written testimony dated July 9, 2025).

- Republic Services was actively drilling gas wells in that area on April 14 and 15, 2025, as part of legally required gas collection system improvements. Although regulations allow 60 months to install gas wells after leaving an area with fresh waste, the Applicant initiated drilling just 4 months after operations moved, demonstrating a proactive approach. Additional gas wells capture more gas, reducing emissions.
- By April 25, 2025, Carbon Mapper imagery shows that the methane plume had diminished and was limited to the landfill footprint.
- Daily Construction Quality Assurance (CQA) reports for that period are available to document this activity.

Figure 1, Coffin Butte Plume (Carbon Mapper, April 25, 2025)

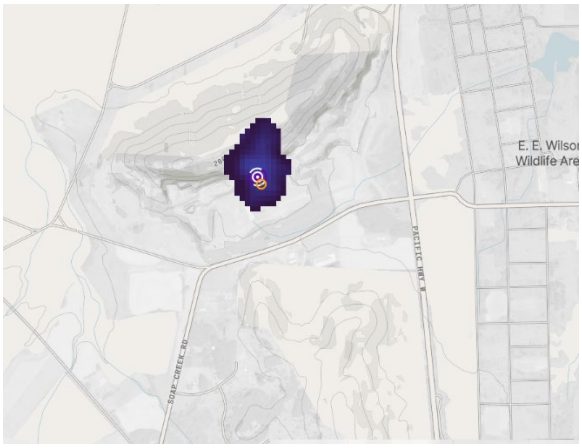
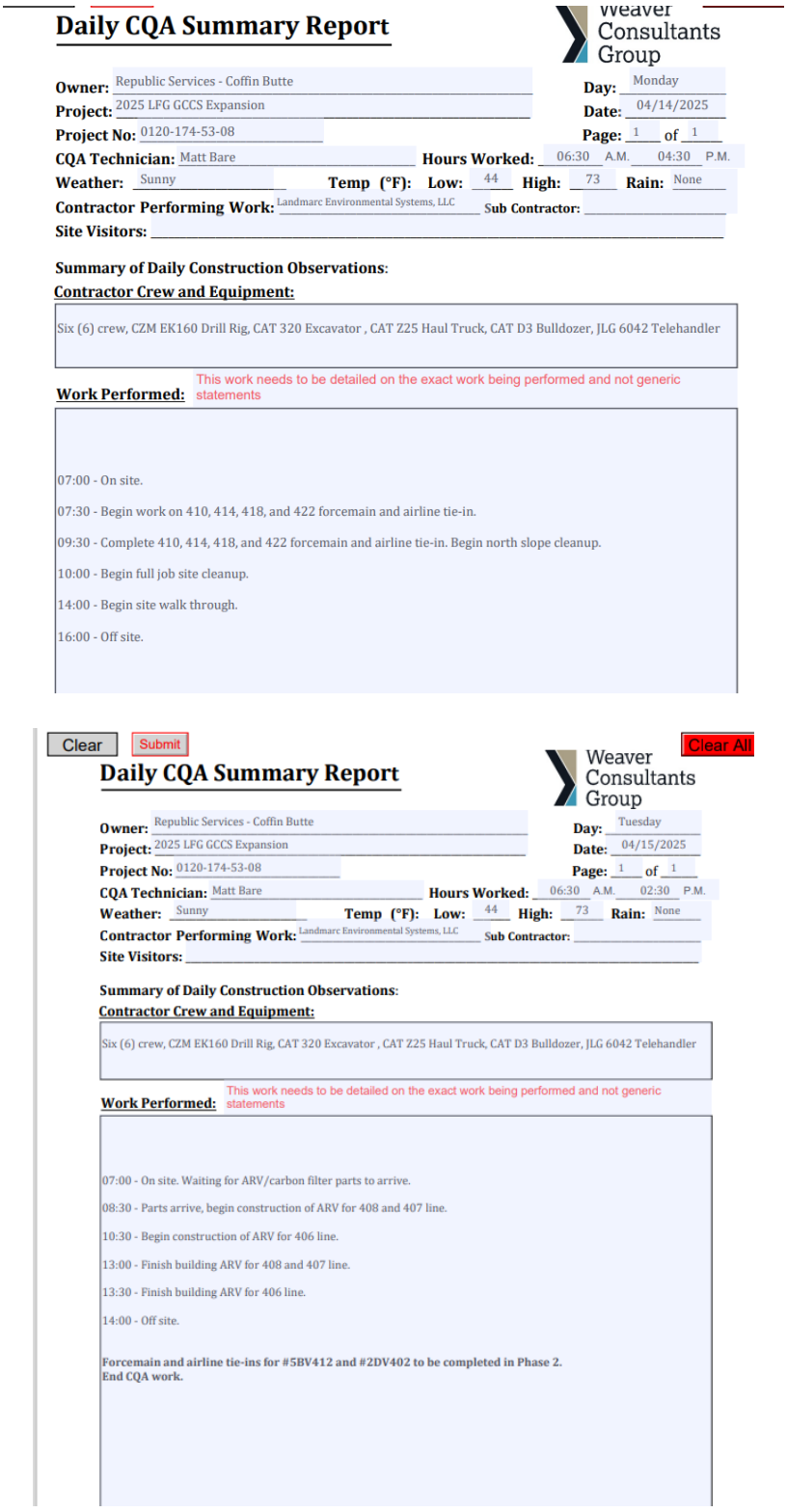


Figure 2, Relevant CQA Records



Daily CQA Summary Report

Weaver Consultants Group

Owner: Republic Services - Coffin Butte
Project: 2025 LFG GCCS Expansion
Project No: 0120-174-53-08
CQA Technician: Matt Bare
Weather: Sunny
Contractor Performing Work: Landmarc Environmental Systems, LLC
Site Visitors:

Day: Monday
Date: 04/14/2025
Page: 1 of 1
Hours Worked: 06:30 A.M. 04:30 P.M.
Temp (°F): **Low:** 44 **High:** 73 **Rain:** None
Sub Contractor:

Summary of Daily Construction Observations:

Contractor Crew and Equipment:

Six (6) crew, CZM EK160 Drill Rig, CAT 320 Excavator , CAT Z25 Haul Truck, CAT D3 Bulldozer, JLG 6042 Telehandler

Work Performed: This work needs to be detailed on the exact work being performed and not generic statements

07:00 - On site.

07:30 - Begin work on 410, 414, 418, and 422 forcemain and airline tie-in.

09:30 - Complete 410, 414, 418, and 422 forcemain and airline tie-in. Begin north slope cleanup.

10:00 - Begin full job site cleanup.

14:00 - Begin site walk through.

16:00 - Off site.

Clear Submit Clear All

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Work Performed: This work needs to be detailed on the exact work being performed and not generic statements

07:00 - On site. Waiting for ARV/carbon filter parts to arrive.

08:30 - Parts arrive, begin construction of ARV for 408 and 407 line.

10:30 - Begin construction of ARV for 406 line.

13:00 - Finish building ARV for 408 and 407 line.

13:30 - Finish building ARV for 406 line.

14:00 - Off site.

Forcemain and airline tie-ins for #5BV412 and #2DV402 to be completed in Phase 2.
End CQA work.

Tremaine and Gail Arkley state that they have smelled landfill odors on their farm in Independence, Oregon, over 7.5 miles from Coffin Butte Landfill (Tremaine and Gail Arkley Testimony dated July 8, 2025).

- Without specific dates, times, and conditions, the claim cannot be fully evaluated, but the likelihood of landfill odors traveling over 7 miles under normal meteorological conditions is low.
- Odor modeling and on-site monitoring indicate that detectable odors are typically confined much closer to the landfill.

Nancy Yialouris states that she filed three odor complaints with Coffin Butte Landfill and DEQ and did not receive any response from landfill staff (Nancy Yialouris Testimony dated July 8, 2025).

- Paul Koster reports that he personally responded to all three complaints and visited the location within 1–2 hours each time.
- On each visit, no landfill odor was detected, and these findings were documented with photos and timestamps.
- While he did not enter private property, he submitted responses to DEQ when the complaints were forwarded through that channel, and those records are on file.

Legal

Ken Ecklund also claims that the Applicant failed to disclose the EPA Section 114 request and that the Disposal Site Advisory Committee (DSAC) uncovered it through a Freedom of Information Act (FOIA) request (Ken Ecklund Testimony dated July 9, 2025).

- This is incorrect. Republic's General Manager informed the DSAC of the Section 114 request and stated during the February 12, 2025 meeting that he would seek approval to provide a copy.
- A copy of the request was subsequently sent to Bailey Payne on February 28, 2025.
- During a following March 12, 2025 DSAC meeting, Mr. Ecklund inaccurately stated that DSAC "found" the records, at which point the General Manager clarified that Republic had voluntarily disclosed the request and provided the document in a timely manner.

Blasting

Geier asserts that the Applicant failed to address the distance and strength of seismic waves from blasting and misrepresented seismic metrics (Geier Annex 1, Comment 9a).

- Blasting-induced fracturing effects are limited to about 15 feet from the borehole.
- Monitoring of seismic effect at 1,100 feet showed PPV well below structural damage thresholds.
- PPV is the correct metric for blasting effects—not shear wave velocity.
- Earthquakes and blasting differ in duration and energy. Groundwater levels have not shown long-term effects from blasting.
- The Applicant will install and monitor sentry wells and nearby residential wells (with permission) to assess any impacts.

Erin Bradley states that she requested blasting be moved to Fridays for scheduling convenience and that communication regarding blasting notifications was inconsistent (Erin Bradley Testimony dated July 8, 2025).

- The drilling contractor would not commit to changing the blasting schedule without first consulting their client. Emails from the contractor confirm that no one from their office stated that blasting would be moved to Fridays.
- Paul Koster informed Ms. Bradley that limiting blasting to Fridays would delay the project and prolong construction, but committed to asking the contractor to blast as late in the day as possible.
- The contractor has verified on multiple occasions that they are calling at least 24 hours in advance of blasting. They have indicated that sometimes calls go unanswered or voicemails cannot be left due to recipients not having voicemail set up.

Camille Hall states that blasting near Cell 6 caused damage to Bill Briskey's property, including the loss of a livestock pond and cracks in a building foundation, and that the Applicant failed to address these issues (Camille Hall Testimony dated July 9, 2025).

- To date, there are no records of any complaints or legal claims submitted regarding property damage caused by Knife River's blasting activities near Cell 6.

- There has been no formal documentation or substantiation provided linking blasting to the alleged damage.

Landfill Height

Rana Foster raises concerns that Condition OP-5, which limits the landfill elevation to 450 feet, lacks enforcement tools and has already been disregarded at the North Landfill (Rana Foster Testimony dated July 8, 2025).

- The expansion landfill will not exceed 450 feet MSL for the top of waste and 453 feet MSL for the top of final cover.
- Due to the geometry of the site and the use of 3H:1V slopes, it is not physically possible for the expansion to exceed the 450-foot elevation limit.
- CUP design drawings show that the expansion area will remain at least 100 to 150 feet below the top of Tampico Ridge, ensuring it will not be visible from properties on the south side of the ridge.

Liner Life

Rana Foster stated that she believes that liner failures or other issues with plastics and chemicals may lead to drainage of landfill leachate into the ground from the leachate storage pond and landfill (Rana Foster Letter dated July 8, 2025).

- Peer-reviewed studies and predictive models indicate that buried **HDPE geomembranes can last several hundred to over 1,000 years under typical landfill conditions**. (Hsuan & Koerner, 1998; Koerner et al., 2005, Rowe et al., 2009; Tian et al., 2016 and 2017; Benson et al., 2016).
- Properly installed GCLs in composite systems (as proposed for the Coffin Butte Landfill expansion) are also expected to have a **very long service life of several hundreds or thousands of years, provided that they are installed correctly** (Rowe, K.R., Orsini, R.B., and Booker, 2004; Benson, C. H., Daniel, D. E., Shackelford, C. D., & Karol, R. H., 2016).
- Composite liner systems containing both an HDPE and GCL, as proposed for the Coffin Butte Landfill expansion, are proven to effectively contain waste and leachate over the long term, countering unsupported concerns about groundwater contamination.
- These liner systems have been extensively studied and are specifically required and approved by the United States Environmental Protection Agency as part of its Subtitle D regulations (40 CFR Part 258).
- The proposed Coffin Butte Landfill expansion will exceed Subtitle D requirements, incorporating three HDPE liners (where only one is required by Subtitle D regulations), a GCL, and a secondary leachate collection and removal system.
- The liner system will be installed with rigorous third-party quality assurance, ensuring compliance with design and regulatory standards and minimizing the risk of failure.
- Construction includes subgrade preparation, wrinkle minimization, seam testing, and cushioning layers to prevent punctures and protect system integrity during waste placement.

Rookeries

Joel Geier raised concerns that conditions of approval recommended by Benton County are poorly considered and are likely to exacerbate impacts on wildlife and adjacent properties. In particular, OP-15(E) (which calls for the entire landfill property including portions zoned as Forest Conservation to be enclosed with a chain link fence) will block movement of elk, deer, and other wildlife through Forest Conservation lands, in direct conflict with the purpose of the FC zone. This condition, proposed by the County to mitigate one demonstrated impact of the landfill (windblown trash), will foreseeably create its own impacts, as elk, deer and the predators which follow them (in particular cougars) will be diverted through agricultural and residential properties. (Joel Geier Testimony dated July 8, 2025).

- The proposed fencing would keep wildlife away from the project area with active landfill operations, including leachate ponds, which are proposed to be constructed in areas that are not currently used for forest operations.
- This area was not found to be a major wildlife corridor. Cougar was observed only one day on the property when trail cameras were installed for over 12 months.

Joel Geier asserts that in Exhibit 43, the applicant's wildlife consultant acknowledges "the landfill can attract a high density of eagles" and that "the high density of eagles and large flocks of other predatory birds" may pose a threat to heron rookeries near the landfill. We agree that the concentrations of eagles and other predatory birds drawn to the landfill pose a risk not just to herons but also to other bird species of concern, in particular Oregon vesper sparrows (candidate for federal listing) and Streaked horned lark (federally listed as Threatened), which are documented to nest within 2 miles and 4 miles of the landfill, respectively (Joel Geier Testimony dated July 8, 2025).

- The proposed development would not significantly increase the population of predatory birds in the area.
- The Oregon Department of Forestry (ODF) and the Oregon Department of Fish and Wildlife (ODFW) wildlife biologists visited the landfill site and noted that it is not suitable habitat for the Oregon vesper sparrow or the streaked horned lark. Potentially, the landfill is drawing predatory birds away from the known sites located over 2 miles away.

Geier asserts that on other matters related to the nesting herons, the applicant's wildlife consultant has demonstrated a poor record (Joel Geier Testimony dated July 8, 2025). To wit:

- In 2021 this same consultant undercounted the number of active nests in the poplar grove ("east rookery") by more than a factor of two, as documented by community members.
- During 2022 this consultant did not record a visit during the month of May when the colony underwent a nesting failure; again, community members noticed and investigated the failure before the applicant's consultant.
- During 2023 through May 2025, the same consultant failed to notice or document heron nesting activity in the Oregon ash grove just across Hwy 99W from one of their observation points.

Geier raised concerns that in their most recent opinion responding to VNEQS concerns (Exhibit 53), the consultant suggests that the new rookery location that they previously failed to notice might be more favorable for heron colony survival because "it is in a mixed conifer/deciduous stand." (Joel Geier Testimony dated July 8, 2025).

- In 2021, Turnstone initially reported the rookery met the minimum threshold number of active nests. 2022 surveys for great blue herons followed the monitoring protocol established in the survey plan approved by ODF and ODFW wildlife biologists. The new nesting area is in close proximity to the collapsed nest but is not necessarily the same individuals.
- If a mitigation and protection plan is needed for the new great blue heron rookery, then the applicant will conduct a full investigation into the structure of the nesting area. Turnstone biologists were not tasked with searching the E.E. Wilson Wildlife Area for new great blue heron nests since the collapse of the east rookery. The rookery should not be approached by curious neighbors or biologists during the breeding period.

Geier commenter raised concerns that the applicant's wildlife consultant also fails to address the impact that a new landfill would have, as a major new topographic obstruction in the herons' flight paths to documented foraging areas in Soap Creek Valley. Heron experts including Dr. Ann Eissinger (cited in previous testimony) have identified flight paths to multiple foraging areas as a critical factor in heron rookery success. (Joel Geier Testimony dated July 8, 2025).

- The new proposed development would not obstruct the flight path of great blue herons to foraging areas west of the project area.

Fire

Mardi Bisland reported that they recall some time ago a huge fire at Coffin Butte Landfill that lit up the night sky. (Mardi Bilsland Letter dated July 11, 2025)

- This must have been the large fire known to occur at the landfill in 1999, as was described in the Coffin Butte fire consultant’s report. At that time the landfill was owned and operated by another party, years prior to Republic Services assuming operations. The only way a fire of that size could have developed would be for tens of acres of landfill waste to be exposed overnight and likely left exposed that way for an extended time of weeks or months without cover. Republic Services limits exposed waste at the working face to under 2 acres during operations each day. Exposed waste is always covered overnight. A fire of that size simply cannot occur now with Republic Services at Coffin Butte Landfill.
- Conditions in 1999 are anecdotal from those familiar with the landfill’s operations and that fire in 1999. Current conditions are facts of current operation and commitments made by Republic Services in the landfill’s operating plan.

Beyond Toxics asserts that proposed landfill expansion will significantly increase fire risks beyond those at the landfill now. The burdens of fire control may be beyond that of Adair Fire Department. The landfill needs a complete log of landfill fire incidents at the site. (Beyond Toxics Letter dated July 9, 2025)

- The proposed landfill expansion and attendant fire risks are the same as those now. They have been and will be adequately managed by on-site staff. There is no reason to believe the future operations will pose any change in attendant landfill fire risks.
- Landfill staff met with Adair Fire in March 2025. Each party agreed they have had a strong history of working well together to mitigate fires and fire risks. Each party pledged to continue that working relationship. Adair Fire did not express concerns regarding ongoing support at that time.
- The Applicant has committed going forward to compile a log and description of any and all landfill fires, no matter how brief and small. Reports will be provided to both DSAC and ODEQ.
- The March 2025 meeting between Adair Fire and Coffin Butte Landfill was recorded in meeting notes and follow-up communication from each side. The Applicant has committed on the record to compiling a complete log of all landfill fires going forward and reporting such fires to DSAC and ODEQ.

Ken Eklund contends that under ODEQ regulation, Republic Services should have replaced landfill gas open flares with an enclosed flare earlier than when they did so. An enclosed flare would have prevented the open flare from causing a grass fire that posed a danger to at least one off-site resident. (Ken Eklund Testimony dated July 9, 2025)

- The open flare was replaced with an enclosed flare timely enough to comply with ODEQ regulations. The grass fire was small and limited in size. It never posed a threat to any off-site properties. Shortly after the grass fire occurred, the grass around the open flare was immediately replaced by gravel, so that a fire like this could not reoccur.
- Facts on written record.

Kate Harris asserts that Adair Fire was never contacted by the county regarding this landfill expansion. (Kate Harris Testimony dated July 9, 2025)

- Landfill staff met with Adair Fire personnel in March 2025. Each side observed that a strong cooperative relationship existed up to that time, and the parties further pledged to continue that relationship and mutual support going forward, including for the expansion.
- The March 2025 meeting between Adair Fire and Coffin Butte was recorded in meeting notes and follow-up communications from each side. Coffin Butte has committed on the record to compiling a complete log of all landfill fires and reporting such to DSAC and ODEQ.

Jeffrey L. Kleinman, on behalf of Valley Neighbors for Environmental Quality, asserts that the history of landfill fires at Coffin Butte is significant. Past fires and future fire risks impose serious interference to adjacent property and the character of the area. Monitoring and logging of landfill fires is deficient. (Jeffrey L. Kleinman Memorandum dated July 8, 2025).

- With the exception of the 1999 landfill fire that occurred with the prior operator, no fire has risen to a level of significance, nor has it ever run the risk of migrating off-site. The 1999 fire cannot possibly reoccur at anywhere near that size with the way Republic Services operates Coffin Butte today.
- Republic Services will compile a log and description of any and all landfill fires going forward, no matter how small, and report them to DSAC and ODEQ. The risks of fires at Coffin Butte going forward cannot and will not impose serious interference to adjacent property nor to the character of the area.

- Historical facts on the written record, along with the professional opinion of the landfill fire consultants, both for P&Z Staff and Coffin Butte.

Rana Foster posed several fire-related questions: What fire control support is available specific to the landfill expansion? Is the water supply of adequate capacity? Who is available to observe landfill fires that break out in off-hours? (Rana Foster Letter dated July 8, 2025)

- The Coffin Butte Landfill's fire consultant report describes the resources that are available to identify, manage, and extinguish landfill fires now. And that these resources and plans will remain in place for the expansion, and will be adequate for the expansion.
- The water source for the water truck is of sufficient capacity to fill the water truck quickly. The spray flow rate on the water truck is also adequate to quickly extinguish any grass fire, as has been demonstrated several times in the past.
- With all waste covered at the end of the day, off-hour fires are rare and not likely to occur. Coffin Butte staff stay on site for a few hours after site closing each day to make sure a hot load received an hour prior does not cause a fire.
- Coffin Butte is investigating technologies that can identify landfill fires and notify the appropriate personnel. Such technologies have not yet been adapted to landfills.
- As reported in the landfill fire consultant's report and in prior rebuttals from the consultant during the P&Z Commission review process.
- Additionally, the Applicant is proposing an amendment to OP-12(A), as set forth in the attached Exhibit 2, which **will require the Applicant to maintain two fire trucks at the site.**

Noise

Rana Foster claims that noise conditions will not be enforceable or have any penalties (Rana Foster Letter dated July 8, 2025).

- This is incorrect. The Applicant will be subject to conditions if approval stated in the CUP and would be enforced by the County. Noncompliance could ultimately result in revocation of the CUP, which would be a substantial penalty.

Camille Hall claims that the noise modeling is inaccurate due to the interaction of on-site equipment noise interacting with atmospheric conditions (Camille Hall Testimony dated July 9, 2025).

- This is misleading. Even though noise models use predictive scenarios to generate results, input assumptions have been validated and the noise model uses a proven international computation standard (ISO 9613 Part 2) to account for atmospheric conditions.

Jeffrey L. Kleinman, on behalf of Valley Neighbors for Environmental Quality, claims that the noise study relies on an outdated and unenforced noise standard that is not entirely applicable to the proposed application (Jeffrey L. Kleinman Memorandum dated July 8, 2025).

- This is misleading, since even though regulation has been defunded by the state legislature, it continues to be updated. The DEQ noise regulations are one of the most comprehensive set of

noise regulations in the pacific northwest. They were developed in response to the Noise Control Act of 1972 and are consistent with the federal guidance published by the EPA following the Act. Community noise regulation has not evolved much since the EPA was defunded in 1982, and as a result, many communities have not updated their regulations, but DEQ continues to update its noise policy, with many updates in the last ten years as recently as 2024 (DEQ17-2024, DEQ25-2018, DEQ24-2018, DEQ23-2018, DEQ22-2018, DEQ 21-2018, DEQ5-2018, DEQ25-2017, DEQ24-2017, DEQ22-2017, DEQ21-2017, DEQ20-2017, DEQ19-2017, and DEQ14-2017).

- The original staff report and supplemental staff report concur with application of the DEQ noise policy to this application.

Kleinman also claims that since the Applicant will not have control over private and commercial haul vehicles, the proposed mitigation to reduce noise from on-site equipment fails to demonstrate compliance (Jeffrey L. Kleinman Memorandum dated July 8, 2025). This claim is also made by Mark Yeager (Mark Yeager Letter dated July 9, 2025).

- This is misleading, since the noise analysis did account for this condition. The 10 dB reduction in on-site equipment emissions is not expected to reduce offsite emissions by 10 dB due to the contributions from haul vehicles that could not reasonably be modified to reduce sound emissions. The overall reduced level at the nearest noise-sensitive property by 5 dB, which accounts for unaltered noise emissions from these haul vehicles.

Mark Yeager claims noise levels from the proposed expansion will affect properties closer than those used in the analysis (Mark Yeager Letter dated July 9, 2025).

- This is misleading, since the DEQ noise standard only applies at properties that are defined as “noise sensitive” and those properties were analyzed, including those immediately adjacent to the site.

Exhibit 1

Proposed Conditions

Amend OP-7(C) as follows (added language underlined, deleted language ~~strikethrough~~):

(C) Applicant's evidence submitted to support the conclusion that the proposed expansion will not seriously interfere with uses on adjacent properties or with the character of the area with regard to odor impacts is based on Applicant's submitted odor studies' assumption that the maximum organic waste acceptance will be no more than 41,110,068 tons by 2052. Accordingly, upon approval of this Conditional Use Permit, Applicant shall comply with the following tonnage caps on annual waste deposited in the landfill evaluated on a twelve-month average basis: Municipal solid waste (MSW) shall not exceed 1.0 million tons per year, and total solid waste inclusive of MSW shall not exceed 1.3 million tons per year. This does not include non-deplete waste (waste that is not deposited in the cell, such as cover materials). These caps shall increase annually following approval of the CUP by the United States Bureau of Labor Statistics Consumer Price Index, except that Applicant shall not accept organic waste exceeding 10% of the modeled 930,373 tons per year through 2052. With County approval these tonnage caps may be exceeded when an extraordinary event, such as fire, floods, and similar events, results in increased waste. ~~.Accordingly, a condition of approval is appropriate to align with the Applicant's studies assumed total organic waste acceptance volume, with provision that the annual organic waste acceptance volumes are within 10% of the modeled 930,373 tons per year through 2052.~~

Replace OP-12 (A) as follows:

(*A) Applicant shall maintain at least two 4,000-gallon+ water trucks at the landfill in good repair so that they are always fully available to help extinguish fires. No more than one of the trucks may leave the landfill property at any given time. At such time as Applicant may replace or update the water trucks or other firefighting infrastructure in the expansion area, such new truck or equipment will provide protection equal to or better than the truck or equipment being replaced.*

Amend OP-15(F) as follows (added language underlined):

(F) Off-Site Litter Management.

(i) Applicant shall expand its litter collection program to include Tampico Road and Soap Creek Road, conducting regular patrols and cleanup operations to address any landfill-related litter.

(ii) Subject to the request and consent of the property owner, Applicant shall clean up litter on a weekly basis on any property that is an "adjacent property" as defined in the Staff Report at a time and day mutually agreeable to Applicant and the property owner. Applicant will ensure that Applicant's employees or contractors are adequately insured and will agree in an access agreement to defend and indemnify the property owner for any damage to their property caused by Applicant's employees or contractors while on the property.

Add a new OP-17 as follows:

OP-17 Compliance Enforcement

In order to assist the County in evaluating Applicant and its compliance with conditions of approval, Applicant shall reimburse the County in an amount not to exceed $80,000 per year to enable the County to retain a qualified consultant or consultants to:

(A) Review compliance with the Operating Conditions of Approval.

(B) Review groundwater compliance.

(C) Review sentinel well records.

(D) Be available to the County as their Coffin Butte Landfill expert.

(E) Perform a monthly inspection of the expansion area to assess compliance or more frequently on reasonable notice if necessary to address complaints or compliance issues.

(F) Perform such other service related to Coffin Butte Landfill as may be requested by the County.

(G) Produce an annual report to the County on subject matters (A) through (F).

Applicant shall reimburse the County for these costs on a monthly basis within 60 days of receipt of an invoice from the County detailing its time and materials costs for the consultant or consultants, This condition of approval shall commence on the date that the Expansion Area is opened for solid waste disposal and will cease on the date the Expansion Area is no longer used for solid waste disposal. The reimbursement cap will increase every year following commencement of the condition by the United States Bureau of Labor Statistics Consumer Price Index.

Exhibit 2

ODEQ Composition Table

Statewide Mixed Route Trucks **Total Tons ==> 420,098**

Material	Field Results	Field Results 90% Conf. Interval	Contam. Corrected	Contam. Corrected 90% Conf. Interval	Clean Tons	Clean Tons 90% Conf. Interval	# Present / # Samps	% Present	Present
TOTAL PAPER	**22.64%**	**(20.41 - 25.39%)**	**16.58%**	**(14.35 - 19.42%)**	**69,665**	**(60,279 - 81,602)**	**94/ 94**	**100.00%**	**94**
Packaging Paper	**11.30%**	**(9.98 - 12.62%)**	**8.54%**	**(7.44 - 9.81%)**	**35,894**	**(31,242 - 41,213)**	**94/ 94**	**100.00%**	**94**
Cardboard incl. wine boxes	**5.38%**	**(4.35 - 6.44%)**	**3.97%**	**(3.14 - 4.90%)**	**16,661**	**(13,194 - 20,576)**	**92/ 94**	**97.87%**	**92**
Wine boxes	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	11	(0 - 33)	1/ 94	1.06%	1
Cardboard/brown bags	5.38%	(4.34 - 6.43%)	3.96%	(3.14 - 4.90%)	16,650	(13,181 - 20,576)	92/ 94	97.87%	92
Low grade Not OK With ONP	1.59%	(1.40 - 1.80%)	1.16%	(0.97 - 1.37%)	4,888	(4,073 - 5,771)	93/ 94	98.94%	93
Polycoats +bleached drink boxes	**1.59%**	**(1.39 - 1.79%)**	**1.12%**	**(0.95 - 1.30%)**	**4,720**	**(3,994 - 5,458)**	**90/ 94**	**95.74%**	**90**
Milk cartons/Drink boxes	**0.15%**	**(0.10 - 0.19%)**	**0.11%**	**(0.08 - 0.15%)**	**470**	**(320 - 623)**	**60/ 94**	**63.83%**	**60**
Gable top (milk) cartons	0.09%	(0.05 - 0.12%)	0.07%	(0.04 - 0.10%)	283	(171 - 423)	43/ 94	45.74%	43
Aseptic drink boxes	0.06%	(0.04 - 0.10%)	0.04%	(0.02 - 0.07%)	187	(99 - 300)	41/ 94	43.62%	41
Other Polycoated paper	1.44%	(1.25 - 1.63%)	1.01%	(0.84 - 1.19%)	4,249	(3,545 - 4,986)	89/ 94	94.68%	89
Nonrecyclable (packaging) paper	**2.74%**	**(1.87 - 3.73%)**	**2.29%**	**(1.55 - 3.18%)**	**9,625**	**(6,508 - 13,360)**	**90/ 94**	**95.74%**	**90**
Waxed corrugated cardboard	0.69%	(0.22 - 1.38%)	0.53%	(0.15 - 1.13%)	2,222	(633 - 4,753)	12/ 94	12.77%	12
Non-compost., non-recycl. paper	2.04%	(1.40 - 2.77%)	1.76%	(1.20 - 2.43%)	7,404	(5,033 - 10,190)	90/ 94	95.74%	90
Other (Non-packaging) Paper	**11.34%**	**(9.37 - 13.94%)**	**8.04%**	**(6.03 - 10.52%)**	**33,772**	**(25,339 - 44,198)**	**94/ 94**	**100.00%**	**94**
Hi grade paper	2.63%	(0.86 - 5.57%)	2.72%	(0.84 - 5.30%)	11,437	(3,535 - 22,263)	81/ 94	86.17%	81
Newspaper	0.62%	(0.49 - 0.75%)	0.46%	(0.35 - 0.58%)	1,944	(1,487 - 2,453)	65/ 94	69.15%	65
Magazines	0.54%	(0.35 - 0.78%)	0.57%	(0.34 - 0.84%)	2,382	(1,438 - 3,539)	37/ 94	39.36%	37
Low grade OK With ONP	1.23%	(1.01 - 1.46%)	0.98%	(0.79 - 1.20%)	4,123	(3,313 - 5,029)	83/ 94	88.30%	83
Hardcover books	0.02%	(0.00 - 0.04%)	0.02%	(0.00 - 0.03%)	71	(5 - 147)	3/ 94	3.19%	3
Other compostable nonrecycl. paper	6.31%	(5.58 - 6.98%)	3.29%	(2.86 - 3.73%)	13,815	(11,998 - 15,655)	93/ 94	98.94%	93
Low-grade paper combined	*2.99%*	*(2.67 - 3.33%)*	*2.27%*	*(1.99 - 2.59%)*	*9,552*	*(8,351 - 10,889)*	*93/ 94*	*98.94%*	*93*
Non-recyclable paper combined	*10.48%*	*(9.41 - 11.71%)*	*6.59%*	*(5.77 - 7.60%)*	*27,690*	*(24,248 - 31,934)*	*93/ 94*	*98.94%*	*93*
Paper drink cartons	*0.15%*	*(0.11 - 0.20%)*	*0.11%*	*(0.08 - 0.15%)*	*481*	*(332 - 637)*	*60/ 94*	*63.83%*	*60*
All recyclable paper	*12.16%*	*(9.88 - 14.91%)*	*9.99%*	*(7.70 - 12.62%)*	*41,975*	*(32,336 - 53,019)*	*94/ 94*	*100.00%*	*94*
TOTAL PLASTIC	**14.15%**	**(12.63 - 15.85%)**	**10.31%**	**(9.01 - 11.68%)**	**43,321**	**(37,848 - 49,071)**	**94/ 94**	**100.00%**	**94**
Rigid Plastic Containers (RPCs)	**2.60%**	**(2.26 - 2.98%)**	**1.94%**	**(1.69 - 2.26%)**	**8,159**	**(7,079 - 9,487)**	**93/ 94**	**98.94%**	**93**
Deposit plastic soft drink/beer bottles	0.09%	(0.08 - 0.11%)	0.07%	(0.06 - 0.08%)	291	(236 - 353)	71/ 94	75.53%	71
Plastic deposit water	0.10%	(0.08 - 0.13%)	0.08%	(0.06 - 0.10%)	322	(250 - 404)	81/ 94	86.17%	81
Plastic deposit in 2018 (juice, etc)	0.23%	(0.17 - 0.33%)	0.17%	(0.12 - 0.25%)	735	(515 - 1,031)	79/ 94	84.04%	79
No-deposit plastic beverage bots.	0.32%	(0.21 - 0.45%)	0.24%	(0.16 - 0.34%)	1,003	(654 - 1,412)	61/ 94	64.89%	61
Other plastic bottles	0.59%	(0.50 - 0.70%)	0.44%	(0.37 - 0.53%)	1,868	(1,559 - 2,211)	85/ 94	90.43%	85
5 Gallon buckets/ Flower Pots	0.14%	(0.04 - 0.26%)	0.10%	(0.03 - 0.19%)	441	(127 - 814)	7/ 94	7.45%	7
Plastic tubs, curb-OK 8oz to 4 gal	0.23%	(0.16 - 0.30%)	0.17%	(0.12 - 0.23%)	707	(500 - 951)	70/ 94	74.47%	70
Other RPCs - tubs, etc.	0.89%	(0.74 - 1.08%)	0.66%	(0.55 - 0.81%)	2,792	(2,299 - 3,402)	91/ 94	96.81%	91
Other rigid plastic packaging	**1.14%**	**(1.01 - 1.28%)**	**1.11%**	**(0.93 - 1.25%)**	**4,646**	**(3,905 - 5,264)**	**93/ 94**	**98.94%**	**93**
Plastic bev. bots. <8oz or >5 gal	0.01%	(0.00 - 0.01%)	0.01%	(0.00 - 0.01%)	24	(1 - 52)	4/ 94	4.26%	4
Small tubs 6+oz but <8oz	0.02%	(0.02 - 0.03%)	0.02%	(0.01 - 0.03%)	89	(62 - 117)	43/ 94	45.74%	43
Bulky other rigid plastic packaging	0.04%	(0.01 - 0.08%)	0.04%	(0.01 - 0.07%)	169	(40 - 311)	6/ 94	6.38%	6
All other rigid plastic packaging	1.07%	(0.94 - 1.21%)	1.04%	(0.87 - 1.19%)	4,363	(3,637 - 5,009)	93/ 94	98.94%	93
Rigid plastic products	**3.68%**	**(2.53 - 4.91%)**	**3.40%**	**(2.33 - 4.56%)**	**14,284**	**(9,802 - 19,159)**	**90/ 94**	**95.74%**	**90**
Polyurethane foam carpet pad	0.39%	(0.01 - 0.80%)	0.37%	(0.01 - 0.78%)	1,551	(23 - 3,266)	4/ 94	4.26%	4
Bulky rigid plastic products	1.67%	(0.83 - 2.65%)	1.53%	(0.73 - 2.44%)	6,409	(3,086 - 10,257)	38/ 94	40.43%	38
Other rigid plastic products	0.75%	(0.60 - 0.90%)	0.73%	(0.56 - 0.88%)	3,061	(2,369 - 3,699)	85/ 94	90.43%	85
Mixed plastic / materials	0.87%	(0.38 - 1.65%)	0.78%	(0.35 - 1.55%)	3,262	(1,450 - 6,524)	64/ 94	68.09%	64
Plastic film - combined	**6.74%**	**(5.85 - 7.66%)**	**3.86%**	**(3.30 - 4.46%)**	**16,231**	**(13,884 - 18,720)**	**94/ 94**	**100.00%**	**94**
Plastic Film - Recyclable	**2.23%**	**(1.90 - 2.59%)**	**1.48%**	**(1.24 - 1.76%)**	**6,211**	**(5,211 - 7,390)**	**93/ 94**	**98.94%**	**93**
Plastic grocery/merchandise bags	0.51%	(0.38 - 0.65%)	0.25%	(0.18 - 0.33%)	1,037	(747 - 1,375)	84/ 94	89.36%	84
Plastic other film recyclable	1.72%	(1.43 - 2.04%)	1.23%	(1.01 - 1.49%)	5,174	(4,244 - 6,272)	92/ 94	97.87%	92
Plastic film - non-recyclable	**4.51%**	**(3.85 - 5.20%)**	**2.39%**	**(2.01 - 2.83%)**	**10,021**	**(8,426 - 11,872)**	**94/ 94**	**100.00%**	**94**
Plastic beverage pouches	0.01%	(0.00 - 0.02%)	0.01%	(0.00 - 0.01%)	33	(11 - 62)	27/ 94	28.72%	27
Plastic garbage bags	2.44%	(1.96 - 2.95%)	1.14%	(0.90 - 1.41%)	4,788	(3,771 - 5,924)	94/ 94	100.00%	94
Plastic film- other nonrecyclable	2.05%	(1.74 - 2.44%)	1.24%	(1.01 - 1.50%)	5,200	(4,262 - 6,292)	93/ 94	98.94%	93
Plastic film packaging - estimated	*2.97%*	*(2.64 - 3.33%)*	*1.86%*	*(1.61 - 2.14%)*	*7,813*	*(6,747 - 8,984)*	*94/ 94*	*100.00%*	*94*
Plastic film products - estimated	*3.76%*	*(3.20 - 4.36%)*	*2.00%*	*(1.68 - 2.36%)*	*8,418*	*(7,059 - 9,900)*	*94/ 94*	*100.00%*	*94*
Plastic beverage containers	*0.77%*	*(0.59 - 0.99%)*	*0.57%*	*(0.44 - 0.75%)*	*2,408*	*(1,850 - 3,136)*	*91/ 94*	*96.81%*	*91*
All recyclable plastic	*3.97%*	*(3.53 - 4.45%)*	*2.78%*	*(2.44 - 3.16%)*	*11,691*	*(10,246 - 13,294)*	*94/ 94*	*100.00%*	*94*
All curbside plastic bottles	*1.35%*	*(1.14 - 1.60%)*	*1.01%*	*(0.85 - 1.21%)*	*4,243*	*(3,564 - 5,073)*	*92/ 94*	*97.87%*	*92*
All curbside plastic tubs	*0.39%*	*(0.28 - 0.53%)*	*0.29%*	*(0.21 - 0.40%)*	*1,237*	*(883 - 1,682)*	*79/ 94*	*84.04%*	*79*
Plastic acceptable at the curb	*1.74%*	*(1.49 - 2.02%)*	*1.30%*	*(1.11 - 1.54%)*	*5,480*	*(4,671 - 6,456)*	*92/ 94*	*97.87%*	*92*
Plastic Packaging	*6.71%*	*(6.11 - 7.41%)*	*4.91%*	*(4.40 - 5.47%)*	*20,618*	*(18,478 - 22,966)*	*94/ 94*	*100.00%*	*94*
Plastic Products	*7.44%*	*(6.29 - 8.73%)*	*5.40%*	*(4.36 - 6.56%)*	*22,703*	*(18,332 - 27,543)*	*94/ 94*	*100.00%*	*94*
OTHER ORGANICS	**48.05%**	**(44.62 - 50.88%)**	**47.78%**	**(44.47 - 50.42%)**	**200,716**	**(186,820 - 211,798)**	**94/ 94**	**100.00%**	**94**
Yard Debris	**2.44%**	**(1.08 - 3.97%)**	**2.51%**	**(1.12 - 4.09%)**	**10,530**	**(4,700 - 17,191)**	**56/ 94**	**59.57%**	**56**
Leaves and grass	**2.17%**	**(0.82 - 3.69%)**	**2.24%**	**(0.86 - 3.82%)**	**9,408**	**(3,633 - 16,047)**	**42/ 94**	**44.68%**	**42**
Grass clippings	0.92%	(0.01 - 2.64%)	0.93%	(0.01 - 2.64%)	3,901	(42 - 11,084)	6/ 94	6.38%	6
Leaves / weeds	1.24%	(0.58 - 2.02%)	1.31%	(0.62 - 2.17%)	5,507	(2,603 - 9,131)	38/ 94	40.43%	38
All prunings and stumps	**0.27%**	**(0.13 - 0.43%)**	**0.27%**	**(0.12 - 0.40%)**	**1,123**	**(493 - 1,698)**	**22/ 94**	**23.40%**	**22**
Small prunings under 2"	0.27%	(0.13 - 0.43%)	0.27%	(0.12 - 0.40%)	1,123	(493 - 1,698)	22/ 94	23.40%	22
Prunings and stumps	**0.00%**	**(0.00 - 0.00%)**	**0.00%**	**(0.00 - 0.00%)**	**0**	**(0 - 0)**	**0/ 94**	**0.00%**	**0**
Large prunings over 2"	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Stumps	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
All Wood	**8.63%**	**(5.74 - 11.83%)**	**8.36%**	**(5.43 - 11.36%)**	**35,120**	**(22,820 - 47,715)**	**80/ 94**	**85.11%**	**80**
Clean lumber & hogged fuel	**1.19%**	**(0.80 - 1.61%)**	**1.09%**	**(0.74 - 1.48%)**	**4,567**	**(3,097 - 6,210)**	**43/ 94**	**45.74%**	**43**
Unpainted lumber	**0.74%**	**(0.41 - 1.11%)**	**0.64%**	**(0.36 - 0.99%)**	**2,709**	**(1,516 - 4,170)**	**33/ 94**	**35.11%**	**33**
Reusable lumber: unpainted	0.17%	(0.01 - 0.34%)	0.17%	(0.01 - 0.34%)	718	(33 - 1,445)	3/ 94	3.19%	3
Clean sawn lumber	0.57%	(0.32 - 0.87%)	0.47%	(0.28 - 0.74%)	1,991	(1,165 - 3,116)	33/ 94	35.11%	33
"Hogged fuel" lumber	**0.46%**	**(0.25 - 0.66%)**	**0.44%**	**(0.24 - 0.64%)**	**1,858**	**(1,004 - 2,677)**	**19/ 94**	**20.21%**	**19**
Clean engineered wood	0.46%	(0.25 - 0.66%)	0.44%	(0.24 - 0.64%)	1,857	(1,003 - 2,675)	18/ 94	19.15%	18
Cedar shakes and shingles	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	1	(0 - 4)	2/ 94	2.13%	2
Painted & treated lumber	**1.26%**	**(0.69 - 1.91%)**	**1.20%**	**(0.65 - 1.82%)**	**5,030**	**(2,747 - 7,625)**	**31/ 94**	**32.98%**	**31**
Painted lumber	**1.09%**	**(0.51 - 1.77%)**	**1.04%**	**(0.50 - 1.71%)**	**4,386**	**(2,099 - 7,198)**	**29/ 94**	**30.85%**	**29**
Reusable lumber: painted	0.20%	(0.03 - 0.46%)	0.20%	(0.03 - 0.46%)	849	(126 - 1,913)	5/ 94	5.32%	5
Other painted lumber	0.88%	(0.45 - 1.40%)	0.84%	(0.43 - 1.35%)	3,537	(1,794 - 5,655)	27/ 94	28.72%	27
Chemically-treated lumber	0.17%	(0.00 - 0.37%)	0.15%	(0.00 - 0.33%)	644	(7 - 1,381)	3/ 94	3.19%	3
Wood pallets and crates	1.09%	(0.43 - 1.82%)	1.09%	(0.42 - 1.84%)	4,584	(1,780 - 7,727)	10/ 94	10.64%	10
Wood furniture	3.10%	(1.00 - 5.62%)	3.04%	(0.98 - 5.48%)	12,773	(4,113 - 23,041)	17/ 94	18.09%	17
Other wood products	0.22%	(0.11 - 0.35%)	0.21%	(0.10 - 0.33%)	863	(424 - 1,390)	51/ 94	54.26%	51
Mixed wood / materials	1.77%	(0.67 - 3.05%)	1.74%	(0.66 - 3.00%)	7,303	(2,776 - 12,613)	25/ 94	26.60%	25
All food	**20.19%**	**(17.87 - 22.73%)**	**21.20%**	**(18.73 - 23.84%)**	**89,059**	**(78,681 - 100,137)**	**93/ 94**	**98.94%**	**93**
Non-packaged bakery goods	0.99%	(0.68 - 1.35%)	1.04%	(0.71 - 1.41%)	4,385	(2,971 - 5,917)	64/ 94	68.09%	64
Packaged bakery goods	0.91%	(0.71 - 1.12%)	0.95%	(0.75 - 1.17%)	4,000	(3,145 - 4,910)	72/ 94	76.60%	72
Non-packaged other veget. Food	**11.35%**	**(9.29 - 13.54%)**	**11.92%**	**(9.70 - 14.23%)**	**50,064**	**(40,770 - 59,784)**	**89/ 94**	**94.68%**	**89**
Unpackaged veg edible	3.22%	(2.23 - 4.36%)	3.38%	(2.34 - 4.59%)	14,201	(9,832 - 19,272)	76/ 94	80.85%	76
Unpackaged veg nonedible	8.13%	(6.54 - 9.98%)	8.54%	(6.84 - 10.46%)	35,863	(28,723 - 43,922)	88/ 94	93.62%	88
Packaged other vegetative food	2.41%	(1.93 - 2.91%)	2.53%	(2.04 - 3.07%)	10,612	(8,549 - 12,882)	78/ 94	82.98%	78
Non-packaged non-vegetative food	**3.15%**	**(2.53 - 3.77%)**	**3.30%**	**(2.65 - 3.95%)**	**13,883**	**(11,146 - 16,609)**	**80/ 94**	**85.11%**	**80**
Unpkg edible meat, eggs, dairy	1.24%	(0.86 - 1.64%)	1.30%	(0.90 - 1.73%)	5,448	(3,790 - 7,273)	59/ 94	62.77%	59
Unpkg nonedible animal food-related	0.92%	(0.64 - 1.19%)	0.96%	(0.67 - 1.25%)	4,048	(2,824 - 5,262)	63/ 94	67.02%	63
Mixed unpackaged foods	0.99%	(0.73 - 1.26%)	1.04%	(0.77 - 1.32%)	4,386	(3,242 - 5,550)	53/ 94	56.38%	53
Packaged non-vegetative food	**1.39%**	**(1.09 - 1.67%)**	**1.46%**	**(1.14 - 1.76%)**	**6,115**	**(4,810 - 7,408)**	**65/ 94**	**69.15%**	**65**
Packaged meat, eggs	0.51%	(0.37 - 0.67%)	0.53%	(0.38 - 0.71%)	2,241	(1,609 - 2,965)	45/ 94	47.87%	45
Packaged dairy	0.40%	(0.30 - 0.51%)	0.42%	(0.31 - 0.54%)	1,778	(1,310 - 2,265)	42/ 94	44.68%	42
Mixed packaged foods	0.48%	(0.29 - 0.67%)	0.50%	(0.30 - 0.71%)	2,097	(1,258 - 2,981)	36/ 94	38.30%	36
All edible food	*11.14%*	*(9.74 - 12.66%)*	*11.70%*	*(10.22 - 13.34%)*	*49,147*	*(42,940 - 56,027)*	*91/ 94*	*96.81%*	*91*

Statewide Mixed Route Trucks **Total Tons ==> 420,098**

Material	Field Results	Field Results 90% Conf. Interval	Contam. Corrected	Contam. Corrected 90% Conf. Interval	Clean Tons	Clean Tons 90% Conf. Interval	# Present / # Samps	% Present	Present
All non-edible food	*9.05%*	*(7.36 - 10.95%)*	*9.50%*	*(7.71 - 11.56%)*	*39,912*	*(32,384 - 48,567)*	*89/ 94*	*94.68%*	*89*
Tires	**0.39%**	**(0.00 - 0.82%)**	**0.39%**	**(0.00 - 0.82%)**	**1,619**	**(0 - 3,431)**	**3/ 94**	**3.19%**	**3**
Automotive Tires	0.39%	(0.00 - 0.82%)	0.39%	(0.00 - 0.82%)	1,619	(0 - 3,431)	2/ 94	2.13%	2
Other tires	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	1/ 94	1.06%	1
Other rubber products	0.76%	(0.34 - 1.28%)	0.79%	(0.34 - 1.30%)	3,302	(1,439 - 5,460)	55/ 94	58.51%	55
Disposable diapers	5.89%	(4.82 - 6.99%)	5.90%	(4.82 - 7.00%)	24,775	(20,253 - 29,416)	67/ 94	71.28%	67
Carpet, Rugs, fiber pads	**1.92%**	**(1.10 - 2.87%)**	**1.80%**	**(1.03 - 2.66%)**	**7,551**	**(4,339 - 11,181)**	**24/ 94**	**25.53%**	**24**
Carpet	1.14%	(0.52 - 1.84%)	1.08%	(0.48 - 1.73%)	4,532	(2,023 - 7,266)	14/ 94	14.89%	14
Rugs	0.67%	(0.26 - 1.16%)	0.61%	(0.23 - 1.05%)	2,546	(979 - 4,415)	12/ 94	12.77%	12
Other carpet/rug pad	0.11%	(0.03 - 0.23%)	0.11%	(0.03 - 0.23%)	474	(109 - 947)	3/ 94	3.19%	3
Textiles & mixed	**5.32%**	**(3.19 - 7.63%)**	**4.20%**	**(2.50 - 6.20%)**	**17,629**	**(10,504 - 26,031)**	**91/ 94**	**96.81%**	**91**
Other textiles	4.67%	(2.56 - 6.89%)	3.68%	(1.99 - 5.68%)	15,467	(8,371 - 23,878)	86/ 94	91.49%	86
Mixed textile / material	0.65%	(0.51 - 0.79%)	0.51%	(0.40 - 0.65%)	2,163	(1,701 - 2,729)	79/ 94	84.04%	79
Asphalt roofing & tarpaper	**0.06%**	**(0.00 - 0.16%)**	**0.06%**	**(0.00 - 0.16%)**	**252**	**(1 - 652)**	**4/ 94**	**4.26%**	**4**
Asphalt roofing - recyclable	0.06%	(0.00 - 0.16%)	0.06%	(0.00 - 0.16%)	251	(0 - 652)	3/ 94	3.19%	3
Asphalt roofing - nonrecyclable	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	1	(0 - 2)	1/ 94	1.06%	1
Furniture + Mattresses	**1.46%**	**(0.29 - 2.45%)**	**1.43%**	**(0.29 - 2.41%)**	**6,024**	**(1,205 - 10,128)**	**7/ 94**	**7.45%**	**7**
Matresses & box springs	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Furniture (mixed material)	*1.46%*	*(0.29 - 2.45%)*	*1.43%*	*(0.29 - 2.41%)*	*6,024*	*(1,205 - 10,128)*	*7/ 94*	*7.45%*	*7*
Other miscellaneous organics	**1.00%**	**(0.63 - 1.48%)**	**1.16%**	**(0.70 - 1.71%)**	**4,855**	**(2,930 - 7,200)**	**74/ 94**	**78.72%**	**74**
Paper composite ceiling tiles	0.05%	(0.00 - 0.16%)	0.05%	(0.00 - 0.15%)	223	(0 - 610)	1/ 94	1.06%	1
Compostable other organics	0.17%	(0.01 - 0.47%)	0.22%	(0.01 - 0.60%)	931	(51 - 2,521)	6/ 94	6.38%	6
Non-compostable other organics	0.78%	(0.49 - 1.17%)	0.88%	(0.55 - 1.33%)	3,702	(2,298 - 5,567)	73/ 94	77.66%	73
GLASS	**2.56%**	**(1.39 - 4.13%)**	**2.58%**	**(1.40 - 4.16%)**	**10,857**	**(5,876 - 17,485)**	**80/ 94**	**85.11%**	**80**
Deposit beverage glass	0.30%	(0.20 - 0.41%)	0.30%	(0.20 - 0.42%)	1,263	(821 - 1,773)	45/ 94	47.87%	45
No-deposit glass containers	**0.83%**	**(0.65 - 1.02%)**	**0.85%**	**(0.65 - 1.05%)**	**3,551**	**(2,738 - 4,393)**	**70/ 94**	**74.47%**	**70**
Deposit beverage glass in 2018	0.09%	(0.05 - 0.13%)	0.09%	(0.05 - 0.13%)	362	(208 - 525)	22/ 94	23.40%	22
Other clear beverage bottles	0.16%	(0.09 - 0.25%)	0.16%	(0.09 - 0.24%)	669	(372 - 1,021)	20/ 94	21.28%	20
Other colored beverage bottles	0.10%	(0.04 - 0.15%)	0.10%	(0.04 - 0.15%)	402	(183 - 633)	13/ 94	13.83%	13
Clear container glass	0.44%	(0.33 - 0.57%)	0.45%	(0.33 - 0.59%)	1,908	(1,387 - 2,496)	47/ 94	50.00%	47
Colored container glass	0.04%	(0.02 - 0.06%)	0.05%	(0.03 - 0.08%)	209	(110 - 333)	15/ 94	15.96%	15
Window and other glass	**1.43%**	**(0.25 - 3.12%)**	**1.44%**	**(0.25 - 3.14%)**	**6,042**	**(1,064 - 13,184)**	**47/ 94**	**50.00%**	**47**
Flat window glass	0.99%	(0.00 - 2.96%)	1.00%	(0.00 - 2.97%)	4,201	(3 - 12,491)	5/ 94	5.32%	5
Total fluorescents	**0.01%**	**(0.00 - 0.01%)**	**0.01%**	**(0.00 - 0.01%)**	**30**	**(6 - 58)**	**5/ 94**	**5.32%**	**5**
Fluorescent tubes	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Compact fluorescent lights	0.01%	(0.00 - 0.01%)	0.01%	(0.00 - 0.01%)	30	(6 - 58)	5/ 94	5.32%	5
Other nonrecyclable glass	0.43%	(0.15 - 0.77%)	0.43%	(0.16 - 0.77%)	1,811	(654 - 3,240)	41/ 94	43.62%	41
Glass Beverage bottles	*0.64%*	*(0.44 - 0.87%)*	*0.64%*	*(0.44 - 0.87%)*	*2,697*	*(1,837 - 3,663)*	*61/ 94*	*64.89%*	*61*
METAL	**5.92%**	**(4.75 - 7.13%)**	**5.74%**	**(4.45 - 6.97%)**	**24,126**	**(18,698 - 29,269)**	**93/ 94**	**98.94%**	**93**
Aluminum	**0.43%**	**(0.34 - 0.53%)**	**0.30%**	**(0.23 - 0.40%)**	**1,265**	**(967 - 1,664)**	**89/ 94**	**94.68%**	**89**
Aluminum beverage cans	**0.16%**	**(0.14 - 0.18%)**	**0.14%**	**(0.12 - 0.16%)**	**587**	**(498 - 686)**	**88/ 94**	**93.62%**	**88**
Deposit aluminum bev. cans	0.14%	(0.12 - 0.17%)	0.12%	(0.10 - 0.15%)	520	(436 - 617)	86/ 94	91.49%	86
Deposit Alum. In 2018	0.02%	(0.01 - 0.02%)	0.02%	(0.01 - 0.02%)	67	(45 - 87)	34/ 94	36.17%	34
Other Aluminum bev. cans	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Aluminum foil / food trays	0.19%	(0.15 - 0.24%)	0.09%	(0.06 - 0.12%)	364	(258 - 522)	81/ 94	86.17%	81
Other aluminum	**0.08%**	**(0.02 - 0.16%)**	**0.07%**	**(0.02 - 0.15%)**	**315**	**(65 - 635)**	**10/ 94**	**10.64%**	**10**
Other Aluminum curbside OK	0.07%	(0.02 - 0.15%)	0.07%	(0.01 - 0.14%)	290	(55 - 599)	9/ 94	9.57%	9
Large Aluminum not curbside OK	0.01%	(0.00 - 0.01%)	0.01%	(0.00 - 0.01%)	24	(7 - 45)	4/ 94	4.26%	4
Other nonferrous metal	**0.04%**	**(0.01 - 0.07%)**	**0.04%**	**(0.02 - 0.07%)**	**163**	**(63 - 288)**	**13/ 94**	**13.83%**	**13**
Nonferrous Metal curbside-OK	0.01%	(0.00 - 0.02%)	0.01%	(0.00 - 0.02%)	42	(11 - 81)	5/ 94	5.32%	5
Nonferrous Metal not curbside-OK	0.03%	(0.01 - 0.06%)	0.03%	(0.01 - 0.06%)	121	(31 - 245)	9/ 94	9.57%	9
Steel (tinned) cans	**0.81%**	**(0.61 - 1.02%)**	**0.76%**	**(0.55 - 0.99%)**	**3,181**	**(2,322 - 4,142)**	**81/ 94**	**86.17%**	**81**
Steel beverage cans	**0.01%**	**(0.00 - 0.02%)**	**0.01%**	**(0.00 - 0.02%)**	**46**	**(17 - 79)**	**8/ 94**	**8.51%**	**8**
Steel/Bimetal Deposit Cans	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Steel/Bimetal Deposit 2018	0.01%	(0.00 - 0.02%)	0.01%	(0.00 - 0.01%)	28	(6 - 56)	6/ 94	6.38%	6
Steel/Bimetal Other Bev. Cans	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	18	(0 - 39)	2/ 94	2.13%	2
Other steel cans	0.79%	(0.61 - 1.01%)	0.75%	(0.54 - 0.97%)	3,135	(2,278 - 4,094)	80/ 94	85.11%	80
White goods	0.15%	(0.00 - 0.44%)	0.15%	(0.00 - 0.44%)	612	(0 - 1,835)	1/ 94	1.06%	1
Used oil filters	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	19	(0 - 56)	1/ 94	1.06%	1
Empty aerosol cans	0.10%	(0.06 - 0.14%)	0.09%	(0.06 - 0.13%)	382	(252 - 535)	41/ 94	43.62%	41
Other ferrous metal	**1.04%**	**(0.73 - 1.39%)**	**1.06%**	**(0.74 - 1.40%)**	**4,437**	**(3,113 - 5,893)**	**73/ 94**	**77.66%**	**73**
Other ferrous metal curb-OK	0.73%	(0.48 - 1.04%)	0.74%	(0.49 - 1.05%)	3,119	(2,066 - 4,425)	70/ 94	74.47%	70
Other ferrous metal not curb-OK	0.31%	(0.13 - 0.51%)	0.31%	(0.13 - 0.51%)	1,318	(547 - 2,155)	15/ 94	15.96%	15
Mixed ferrous/non-ferrous	**0.10%**	**(0.03 - 0.20%)**	**0.10%**	**(0.03 - 0.20%)**	**434**	**(130 - 852)**	**7/ 94**	**7.45%**	**7**
Mixed ferrous/non-ferr. curb-OK	0.04%	(0.00 - 0.12%)	0.04%	(0.00 - 0.12%)	175	(3 - 492)	4/ 94	4.26%	4
Mixed ferrous/non-ferr. not curb-OK	0.06%	(0.00 - 0.13%)	0.06%	(0.00 - 0.13%)	259	(12 - 526)	4/ 94	4.26%	4
Mixed Metal / Material	1.36%	(0.84 - 1.92%)	1.17%	(0.61 - 1.76%)	4,930	(2,574 - 7,381)	45/ 94	47.87%	45
Computers, brown goods, small apl.	**1.90%**	**(1.11 - 2.76%)**	**2.07%**	**(1.17 - 2.93%)**	**8,703**	**(4,927 - 12,315)**	**30/ 94**	**31.91%**	**30**
Computers & monitors	**0.01%**	**(0.00 - 0.04%)**	**0.01%**	**(0.00 - 0.04%)**	**59**	**(0 - 166)**	**2/ 94**	**2.13%**	**2**
Computers CPU Units	0.01%	(0.00 - 0.04%)	0.01%	(0.00 - 0.04%)	59	(0 - 166)	2/ 94	2.13%	2
Computer monitor CRTs	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
TVs, other CRTs, brown goods	**1.40%**	**(0.74 - 2.17%)**	**1.49%**	**(0.77 - 2.22%)**	**6,246**	**(3,253 - 9,321)**	**21/ 94**	**22.34%**	**21**
TVs	0.62%	(0.05 - 1.34%)	0.62%	(0.05 - 1.34%)	2,619	(219 - 5,630)	3/ 94	3.19%	3
Printers	0.39%	(0.06 - 0.72%)	0.39%	(0.06 - 0.72%)	1,630	(242 - 3,018)	4/ 94	4.26%	4
Computer mice+keyboards	0.01%	(0.00 - 0.02%)	0.01%	(0.00 - 0.02%)	37	(3 - 95)	3/ 94	3.19%	3
Microwaves	0.21%	(0.00 - 0.43%)	0.21%	(0.00 - 0.43%)	887	(0 - 1,817)	2/ 94	2.13%	2
Other consumer elect./brown goods	0.17%	(0.07 - 0.30%)	0.26%	(0.09 - 0.44%)	1,074	(378 - 1,850)	14/ 94	14.89%	14
Small Appliances-non electronic	0.49%	(0.08 - 0.96%)	0.57%	(0.09 - 1.10%)	2,397	(383 - 4,625)	11/ 94	11.70%	11
Total ferrous	*2.14%*	*(1.75 - 2.61%)*	*2.11%*	*(1.69 - 2.58%)*	*8,847*	*(7,119 - 10,833)*	*90/ 94*	*95.74%*	*90*
Total non-ferrous	*0.52%*	*(0.41 - 0.63%)*	*0.39%*	*(0.30 - 0.50%)*	*1,646*	*(1,262 - 2,102)*	*89/ 94*	*94.68%*	*89*
Recycl. metal excl. electronics, sm. apl.	*2.66%*	*(2.22 - 3.17%)*	*2.50%*	*(2.06 - 3.01%)*	*10,493*	*(8,657 - 12,657)*	*92/ 94*	*97.87%*	*92*
OTHER INORGANICS	**5.04%**	**(3.69 - 6.55%)**	**5.15%**	**(3.79 - 6.70%)**	**21,640**	**(15,923 - 28,147)**	**75/ 94**	**79.79%**	**75**
Rock, dirt, litter	3.66%	(2.62 - 5.02%)	3.77%	(2.69 - 5.18%)	15,834	(11,298 - 21,763)	65/ 94	69.15%	65
Rock, brick, dirt	0.99%	(0.47 - 1.57%)	1.10%	(0.50 - 1.80%)	4,631	(2,118 - 7,546)	31/ 94	32.98%	31
Rock, concrete, brick	0.24%	(0.07 - 0.43%)	0.24%	(0.07 - 0.44%)	1,020	(301 - 1,845)	10/ 94	10.64%	10
Soil, sand, dirt	0.75%	(0.27 - 1.37%)	0.86%	(0.30 - 1.59%)	3,612	(1,260 - 6,659)	23/ 94	24.47%	23
Pet litter, animal feces	2.67%	(1.69 - 3.84%)	2.67%	(1.69 - 3.84%)	11,203	(7,093 - 16,114)	53/ 94	56.38%	53
Gypsum wallboard	**0.20%**	**(0.06 - 0.37%)**	**0.20%**	**(0.05 - 0.36%)**	**823**	**(231 - 1,524)**	**10/ 94**	**10.64%**	**10**
Gypsum wallboard NEW	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Gypsum wallboard OLD	0.20%	(0.06 - 0.37%)	0.20%	(0.05 - 0.36%)	823	(231 - 1,524)	10/ 94	10.64%	10
Fiberglass Insulation	0.24%	(0.04 - 0.49%)	0.23%	(0.04 - 0.47%)	986	(156 - 1,979)	5/ 94	5.32%	5
Other miscellaneous inorganics	0.94%	(0.34 - 1.64%)	0.95%	(0.34 - 1.65%)	3,996	(1,427 - 6,942)	34/ 94	36.17%	34
"MEDICAL WASTES"	1.23%	(0.49 - 2.08%)	1.23%	(0.49 - 2.08%)	5,173	(2,047 - 8,721)	25/ 94	26.60%	25

Statewide Mixed Route Trucks **Total Tons ==> 420,098**

Material	Field Results	Field Results 90% Conf. Interval	Contam. Corrected	Contam. Corrected 90% Conf. Interval	Clean Tons	Clean Tons 90% Conf. Interval	# Present / # Samps	% Present	Present
HAZARDOUS MATERIALS	**0.41%**	**(0.18 - 0.65%)**	**0.42%**	**(0.18 - 0.67%)**	**1,745**	**(760 - 2,811)**	**45/ 94**	**47.87%**	**45**
Lead-acid batteries	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Dry-cell batteries	0.05%	(0.02 - 0.08%)	0.06%	(0.02 - 0.09%)	244	(96 - 392)	28/ 94	29.79%	28
Latex paint	0.24%	(0.01 - 0.48%)	0.24%	(0.01 - 0.48%)	1,004	(24 - 2,007)	4/ 94	4.26%	4
Oil paints	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	17	(0 - 36)	2/ 94	2.13%	2
Motor oil	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	12	(0 - 28)	2/ 94	2.13%	2
Other flammables	0.01%	(0.00 - 0.01%)	0.01%	(0.00 - 0.01%)	28	(0 - 57)	2/ 94	2.13%	2
Pesticides / herbicides	0.01%	(0.00 - 0.01%)	0.01%	(0.00 - 0.01%)	29	(7 - 59)	3/ 94	3.19%	3
Corrosive cleaners	0.02%	(0.00 - 0.04%)	0.02%	(0.00 - 0.04%)	74	(9 - 147)	5/ 94	5.32%	5
Asbestos	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Mercury-containing items	0.00%	(0.00 - 0.00%)	0.00%	(0.00 - 0.00%)	0	(0 - 0)	0/ 94	0.00%	0
Ammunition and fireworks	0.01%	(0.00 - 0.03%)	0.01%	(0.00 - 0.03%)	42	(0 - 127)	1/ 94	1.06%	1
Compressed gas cylinders	0.00%	(0.00 - 0.01%)	0.00%	(0.00 - 0.01%)	20	(0 - 51)	2/ 94	2.13%	2
Other hazardous chemicals	0.05%	(0.02 - 0.08%)	0.05%	(0.02 - 0.08%)	189	(69 - 337)	13/ 94	13.83%	13
Unknown hazardous chemicals	0.02%	(0.00 - 0.04%)	0.02%	(0.00 - 0.04%)	84	(12 - 176)	4/ 94	4.26%	4
Total packaging	*24.11%*	*(21.56 - 27.09%)*	*19.49%*	*(16.90 - 22.40%)*	*81,880*	*(70,995 - 94,095)*	*94/ 94*	*100.00%*	*94*
Total products	*48.66%*	*(44.66 - 52.40%)*	*41.88%*	*(38.00 - 45.35%)*	*175,943*	*(159,644 - 190,505)*	*94/ 94*	*100.00%*	*94*
Total non-manufactured	*27.23%*	*(24.46 - 30.02%)*	*28.43%*	*(25.62 - 31.32%)*	*119,420*	*(107,617 - 131,580)*	*93/ 94*	*98.94%*	*93*
Total organic	*86.40%*	*(84.41 - 88.21%)*	*76.23%*	*(74.09 - 77.97%)*	*320,240*	*(311,260 - 327,558)*	*94/ 94*	*100.00%*	*94*
Total non-organic	*13.60%*	*(11.79 - 15.59%)*	*13.57%*	*(11.66 - 15.52%)*	*57,003*	*(48,965 - 65,179)*	*93/ 94*	*98.94%*	*93*
Compostable	*57.24%*	*(53.82 - 60.57%)*	*52.47%*	*(48.81 - 55.79%)*	*220,436*	*(205,050 - 234,372)*	*94/ 94*	*100.00%*	*94*
Compostable-target	*34.73%*	*(31.29 - 38.35%)*	*32.52%*	*(29.19 - 35.86%)*	*136,624*	*(122,621 - 150,661)*	*94/ 94*	*100.00%*	*94*
Curbside recyclables	*16.96%*	*(14.64 - 19.68%)*	*14.25%*	*(11.86 - 16.86%)*	*59,881*	*(49,814 - 70,832)*	*94/ 94*	*100.00%*	*94*
Recoverable (recycl., compost, energy)	*65.05%*	*(62.24 - 67.73%)*	*58.19%*	*(55.22 - 60.91%)*	*244,440*	*(231,989 - 255,889)*	*94/ 94*	*100.00%*	*94*
Recyclable (incl. energy, not compost)	*35.24%*	*(32.30 - 38.13%)*	*30.44%*	*(27.51 - 33.15%)*	*127,883*	*(115,561 - 139,270)*	*94/ 94*	*100.00%*	*94*
Compostable but not recyclable	*29.80%*	*(26.88 - 32.83%)*	*27.75%*	*(24.75 - 30.79%)*	*116,557*	*(103,978 - 129,337)*	*94/ 94*	*100.00%*	*94*
Not recoverable (inverse of recoverable)	*34.95%*	*(32.27 - 37.76%)*	*31.61%*	*(28.87 - 34.30%)*	*132,802*	*(121,285 - 144,081)*	*94/ 94*	*100.00%*	*94*
Water and Residue (Contamination)	*0.00%*	*(0.00 - 0.00%)*	*10.20%*	*(9.15 - 11.71%)*	*42,855*	*(38,428 - 49,179)*	*0/ 0*	*0.00%*	*0*
Supermix & fines	*1.10%*	*(0.00 - 0.00%)*	*1.10%*	*(0.00 - 0.00%)*	*4,607*	*(0 - 0)*	*90/ 94*	*95.74%*	*90*
Supermix	*0.54%*	*(0.00 - 0.00%)*	*0.54%*	*(0.00 - 0.00%)*	*2,288*	*(0 - 0)*	*66/ 94*	*70.21%*	*66*
Fines	*0.55%*	*(0.00 - 0.00%)*	*0.55%*	*(0.00 - 0.00%)*	*2,319*	*(0 - 0)*	*87/ 94*	*92.55%*	*87*

Statewide Mixed Route Trucks

Material	Field Low 5%	Field High 5%	Corrected Low 5%	Corrected High 5%	Clean Tons Low 5%	Clean Tons High 5%	Group	EOrd	TonsAlloc	ChProb
TOTAL PAPER	**20.41%**	**25.39%**	**14.35%**	**19.42%**	**60,279**	**81,602**	**F16TOTMIX**	**201**	**420,098**	**0**
Packaging Paper	**9.98%**	**12.62%**	**7.44%**	**9.81%**	**31,242**	**41,213**	**F16TOTMIX**	**202**	**420,098**	**0**
Cardboard incl. wine boxes	**4.35%**	**6.44%**	**3.14%**	**4.90%**	**13,194**	**20,576**	**F16TOTMIX**	**207**	**420,098**	**0**
Wine boxes	0.00%	0.01%	0.00%	0.01%	0	33	F16TOTMIX	3	420,098	0
Cardboard/brown bags	4.34%	6.43%	3.14%	4.90%	13,181	20,576	F16TOTMIX	4	420,098	0
Low grade Not OK With ONP	1.40%	1.80%	0.97%	1.37%	4,073	5,771	F16TOTMIX	10	420,098	0
Polycoats +bleached drink boxes	**1.39%**	**1.79%**	**0.95%**	**1.30%**	**3,994**	**5,458**	**F16TOTMIX**	**206**	**420,098**	**0**
Milk cartons/Drink boxes	**0.10%**	**0.19%**	**0.08%**	**0.15%**	**320**	**623**	**F16TOTMIX**	**208**	**420,098**	**0**
Gable top (milk) cartons	0.05%	0.12%	0.04%	0.10%	171	423	F16TOTMIX	1	420,098	0
Aseptic drink boxes	0.04%	0.10%	0.02%	0.07%	99	300	F16TOTMIX	2	420,098	0
Other Polycoated paper	1.25%	1.63%	0.84%	1.19%	3,545	4,986	F16TOTMIX	11	420,098	0
Nonrecyclable (packaging) paper	**1.87%**	**3.73%**	**1.55%**	**3.18%**	**6,508**	**13,360**	**F16TOTMIX**	**287**	**420,098**	**0**
Waxed corrugated cardboard	0.22%	1.38%	0.15%	1.13%	633	4,753	F16TOTMIX	5	420,098	0
Non-compost., non-recycl. paper	1.40%	2.77%	1.20%	2.43%	5,033	10,190	F16TOTMIX	14	420,098	0
Other (Non-packaging) Paper	**9.37%**	**13.94%**	**6.03%**	**10.52%**	**25,339**	**44,198**	**F16TOTMIX**	**203**	**420,098**	**0**
Hi grade paper	0.86%	5.57%	0.84%	5.30%	3,535	22,263	F16TOTMIX	6	420,098	0
Newspaper	0.49%	0.75%	0.35%	0.58%	1,487	2,453	F16TOTMIX	7	420,098	0
Magazines	0.35%	0.78%	0.34%	0.84%	1,438	3,539	F16TOTMIX	8	420,098	0
Low grade OK With ONP	1.01%	1.46%	0.79%	1.20%	3,313	5,029	F16TOTMIX	9	420,098	0
Hardcover books	0.00%	0.04%	0.00%	0.03%	5	147	F16TOTMIX	12	420,098	0
Other compostable nonrecycl. paper	5.58%	6.98%	2.86%	3.73%	11,998	15,655	F16TOTMIX	13	420,098	0
Low-grade paper combined	*2.67%*	*3.33%*	*1.99%*	*2.59%*	*8,351*	*10,889*	*F16TOTMIX*	*204*	*420,098*	*0*
Non-recyclable paper combined	*9.41%*	*11.71%*	*5.77%*	*7.60%*	*24,248*	*31,934*	*F16TOTMIX*	*205*	*420,098*	*0*
Paper drink cartons	*0.11%*	*0.20%*	*0.08%*	*0.15%*	*332*	*637*	*F16TOTMIX*	*209*	*420,098*	*0*
All recyclable paper	*9.88%*	*14.91%*	*7.70%*	*12.62%*	*32,336*	*53,019*	**F16TOTMIX**	**210**	**420,098**	**0**
TOTAL PLASTIC	**12.63%**	**15.85%**	**9.01%**	**11.68%**	**37,848**	**49,071**	**F16TOTMIX**	**211**	**420,098**	**0**
Rigid Plastic Containers (RPCs)	**2.26%**	**2.98%**	**1.69%**	**2.26%**	**7,079**	**9,487**	**F16TOTMIX**	**213**	**420,098**	**0**
Deposit plastic soft drink/beer bottles	0.08%	0.11%	0.06%	0.08%	236	353	F16TOTMIX	15	420,098	0
Plastic deposit water	0.08%	0.13%	0.06%	0.10%	250	404	F16TOTMIX	16	420,098	0
Plastic deposit in 2018 (juice, etc)	0.17%	0.33%	0.12%	0.25%	515	1,031	F16TOTMIX	17	420,098	0
No-deposit plastic beverage bots.	0.21%	0.45%	0.16%	0.34%	654	1,412	F16TOTMIX	18	420,098	0
Other plastic bottles	0.50%	0.70%	0.37%	0.53%	1,559	2,211	F16TOTMIX	20	420,098	0
5 Gallon buckets/ Flower Pots	0.04%	0.26%	0.03%	0.19%	127	814	F16TOTMIX	21	420,098	0
Plastic tubs, curb-OK 8oz to 4 gal	0.16%	0.30%	0.12%	0.23%	500	951	F16TOTMIX	22	420,098	0
Other RPCs - tubs, etc.	0.74%	1.08%	0.55%	0.81%	2,299	3,402	F16TOTMIX	23	420,098	0
Other rigid plastic packaging	**1.01%**	**1.28%**	**0.93%**	**1.25%**	**3,905**	**5,264**	**F16TOTMIX**	**215**	**420,098**	**0**
Plastic bev. bots. <8oz or >5 gal	0.00%	0.01%	0.00%	0.01%	1	52	F16TOTMIX	19	420,098	0
Small tubs 6+oz but <8oz	0.02%	0.03%	0.01%	0.03%	62	117	F16TOTMIX	24	420,098	0
Bulky other rigid plastic packaging	0.01%	0.08%	0.01%	0.07%	40	311	F16TOTMIX	25	420,098	0
All other rigid plastic packaging	0.94%	1.21%	0.87%	1.19%	3,637	5,009	F16TOTMIX	26	420,098	0
Rigid plastic products	**2.53%**	**4.91%**	**2.33%**	**4.56%**	**9,802**	**19,159**	**F16TOTMIX**	**218**	**420,098**	**0**
Polyurethane foam carpet pad	0.01%	0.80%	0.01%	0.78%	23	3,266	F16TOTMIX	67	420,098	0
Bulky rigid plastic products	0.83%	2.65%	0.73%	2.44%	3,086	10,257	F16TOTMIX	27	420,098	0
Other rigid plastic products	0.60%	0.90%	0.56%	0.88%	2,369	3,699	F16TOTMIX	28	420,098	0
Mixed plastic / materials	0.38%	1.65%	0.35%	1.55%	1,450	6,524	*F16TOTMIX*	29	420,098	0
Plastic film - combined	**5.85%**	**7.66%**	**3.30%**	**4.46%**	**13,884**	**18,720**	***F16TOTMIX***	**220**	**420,098**	**0**
Plastic Film - Recyclable	**1.90%**	**2.59%**	**1.24%**	**1.76%**	**5,211**	**7,390**	***F16TOTMIX***	**295**	**420,098**	**0**
Plastic grocery/merchandise bags	0.38%	0.65%	0.18%	0.33%	747	1,375	*F16TOTMIX*	31	420,098	0
Plastic other film recyclable	1.43%	2.04%	1.01%	1.49%	4,244	6,272	*F16TOTMIX*	32	420,098	0
Plastic film - non-recyclable	**3.85%**	**5.20%**	**2.01%**	**2.83%**	**8,426**	**11,872**	***F16TOTMIX***	**221**	**420,098**	**0**
Plastic beverage pouches	0.00%	0.02%	0.00%	0.01%	11	62	F16TOTMIX	30	420,098	0
Plastic garbage bags	1.96%	2.95%	0.90%	1.41%	3,771	5,924	F16TOTMIX	33	420,098	0
Plastic film- other nonrecyclable	1.74%	2.44%	1.01%	1.50%	4,262	6,292	F16TOTMIX	34	420,098	0
Plastic film packaging - estimated	*2.64%*	*3.33%*	*1.61%*	*2.14%*	*6,747*	*8,984*	*F16TOTMIX*	*216*	*420,098*	*0*
Plastic film products - estimated	*3.20%*	*4.36%*	*1.68%*	*2.36%*	*7,059*	*9,900*	*F16TOTMIX*	*219*	*420,098*	*0*
Plastic beverage containers	*0.59%*	*0.99%*	*0.44%*	*0.75%*	*1,850*	*3,136*	*F16TOTMIX*	*222*	*420,098*	*0*
All recyclable plastic	*3.53%*	*4.45%*	*2.44%*	*3.16%*	*10,246*	*13,294*	*F16TOTMIX*	*224*	*420,098*	*0*
All curbside plastic bottles	*1.14%*	*1.60%*	*0.85%*	*1.21%*	*3,564*	*5,073*	*F16TOTMIX*	*225*	*420,098*	*0*
All curbside plastic tubs	*0.28%*	*0.53%*	*0.21%*	*0.40%*	*883*	*1,682*	*F16TOTMIX*	*226*	*420,098*	*0*
Plastic acceptable at the curb	*1.49%*	*2.02%*	*1.11%*	*1.54%*	*4,671*	*6,456*	*F16TOTMIX*	*227*	*420,098*	*0*
Plastic Packaging	*6.11%*	*7.41%*	*4.40%*	*5.47%*	*18,478*	*22,966*	*F16TOTMIX*	*212*	*420,098*	*0*
Plastic Products	*6.29%*	*8.73%*	*4.36%*	*6.56%*	*18,332*	*27,543*	*F16TOTMIX*	*217*	*420,098*	*0*
OTHER ORGANICS	**44.62%**	**50.88%**	**44.47%**	**50.42%**	**186,820**	**211,798**	**F16TOTMIX**	**228**	**420,098**	**0**
Yard Debris	**1.08%**	**3.97%**	**1.12%**	**4.09%**	**4,700**	**17,191**	**F16TOTMIX**	**229**	**420,098**	**0**
Leaves and grass	**0.82%**	**3.69%**	**0.86%**	**3.82%**	**3,633**	**16,047**	**F16TOTMIX**	**230**	**420,098**	**0**
Grass clippings	0.01%	2.64%	0.01%	2.64%	42	11,084	F16TOTMIX	35	420,098	0
Leaves / weeds	0.58%	2.02%	0.62%	2.17%	2,603	9,131	F16TOTMIX	36	420,098	0
All prunings and stumps	**0.13%**	**0.43%**	**0.12%**	**0.40%**	**493**	**1,698**	**F16TOTMIX**	**232**	**420,098**	**0**
Small prunings under 2"	0.13%	0.43%	0.12%	0.40%	493	1,698	F16TOTMIX	37	420,098	0
Prunings and stumps	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0**	**0**	**F16TOTMIX**	**231**	**420,098**	**1001**
Large prunings over 2"	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	38	420,098	0
Stumps	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	39	420,098	0
All Wood	**5.74%**	**11.83%**	**5.43%**	**11.36%**	**22,820**	**47,715**	**F16TOTMIX**	**233**	**420,098**	**0**
Clean lumber & hogged fuel	**0.80%**	**1.61%**	**0.74%**	**1.48%**	**3,097**	**6,210**	**F16TOTMIX**	**234**	**420,098**	**0**
Unpainted lumber	**0.41%**	**1.11%**	**0.36%**	**0.99%**	**1,516**	**4,170**	**F16TOTMIX**	**235**	**420,098**	**0**
Reusable lumber: unpainted	0.01%	0.34%	0.01%	0.34%	33	1,445	F16TOTMIX	40	420,098	0
Clean sawn lumber	0.32%	0.87%	0.28%	0.74%	1,165	3,116	F16TOTMIX	41	420,098	0
"Hogged fuel" lumber	**0.25%**	**0.66%**	**0.24%**	**0.64%**	**1,004**	**2,677**	**F16TOTMIX**	**236**	**420,098**	**0**
Clean engineered wood	0.25%	0.66%	0.24%	0.64%	1,003	2,675	F16TOTMIX	42	420,098	0
Cedar shakes and shingles	0.00%	0.00%	0.00%	0.00%	0	4	F16TOTMIX	47	420,098	0
Painted & treated lumber	**0.69%**	**1.91%**	**0.65%**	**1.82%**	**2,747**	**7,625**	**F16TOTMIX**	**237**	**420,098**	**0**
Painted lumber	**0.51%**	**1.77%**	**0.50%**	**1.71%**	**2,099**	**7,198**	**F16TOTMIX**	**238**	**420,098**	**0**
Reusable lumber: painted	0.03%	0.46%	0.03%	0.46%	126	1,913	F16TOTMIX	43	420,098	0
Other painted lumber	0.45%	1.40%	0.43%	1.35%	1,794	5,655	F16TOTMIX	44	420,098	0
Chemically-treated lumber	0.00%	0.37%	0.00%	0.33%	7	1,381	F16TOTMIX	45	420,098	0
Wood pallets and crates	0.43%	1.82%	0.42%	1.84%	1,780	7,727	F16TOTMIX	46	420,098	0
Wood furniture	1.00%	5.62%	0.98%	5.48%	4,113	23,041	F16TOTMIX	48	420,098	0
Other wood products	0.11%	0.35%	0.10%	0.33%	424	1,390	F16TOTMIX	49	420,098	0
Mixed wood / materials	0.67%	3.05%	0.66%	3.00%	2,776	12,613	F16TOTMIX	50	420,098	0
All food	**17.87%**	**22.73%**	**18.73%**	**23.84%**	**78,681**	**100,137**	**F16TOTMIX**	239	420,098	0
Non-packaged bakery goods	0.68%	1.35%	0.71%	1.41%	2,971	5,917	F16TOTMIX	51	420,098	0
Packaged bakery goods	0.71%	1.12%	0.75%	1.17%	3,145	4,910	F16TOTMIX	52	420,098	0
Non-packaged other veget. Food	**9.29%**	**13.54%**	**9.70%**	**14.23%**	**40,770**	**59,784**	**F16TOTMIX**	**289**	**420,098**	**0**
Unpackaged veg edible	2.23%	4.36%	2.34%	4.59%	9,832	19,272	F16TOTMIX	53	420,098	0
Unpackaged veg nonedible	6.54%	9.98%	6.84%	10.46%	28,723	43,922	F16TOTMIX	54	420,098	0
Packaged other vegetative food	1.93%	2.91%	2.04%	3.07%	8,549	12,882	F16TOTMIX	55	420,098	0
Non-packaged non-vegetative food	**2.53%**	**3.77%**	**2.65%**	**3.95%**	**11,146**	**16,609**	**F16TOTMIX**	**291**	**420,098**	**0**
Unpkg edible meat, eggs, dairy	0.86%	1.64%	0.90%	1.73%	3,790	7,273	F16TOTMIX	56	420,098	0
Unpkg nonedible animal food-related	0.64%	1.19%	0.67%	1.25%	2,824	5,262	F16TOTMIX	57	420,098	0
Mixed unpackaged foods	0.73%	1.26%	0.77%	1.32%	3,242	5,550	F16TOTMIX	60	420,098	0
Packaged non-vegetative food	**1.09%**	**1.67%**	**1.14%**	**1.76%**	**4,810**	**7,408**	**F16TOTMIX**	**292**	**420,098**	**0**
Packaged meat, eggs	0.37%	0.67%	0.38%	0.71%	1,609	2,965	F16TOTMIX	58	420,098	0
Packaged dairy	0.30%	0.51%	0.31%	0.54%	1,310	2,265	F16TOTMIX	59	420,098	0
Mixed packaged foods	0.29%	0.67%	0.30%	0.71%	1,258	2,981	F16TOTMIX	61	420,098	0
All edible food	*9.74%*	*12.66%*	*10.22%*	*13.34%*	*42,940*	*56,027*	*F16TOTMIX*	*293*	*420,098*	*0*

Statewide Mixed Route Trucks

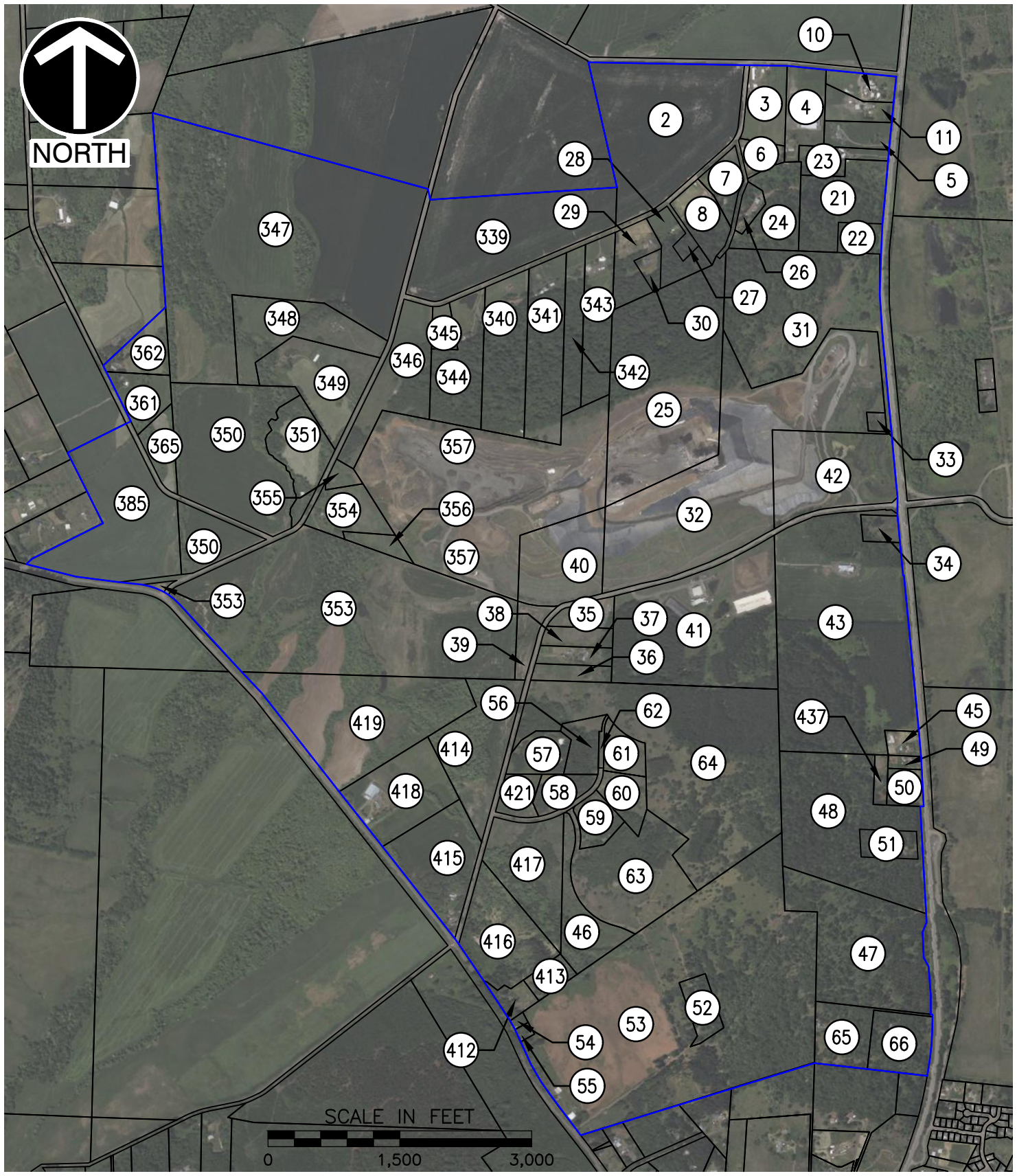
Material	Field Low 5%	Field High 5%	Corrected Low 5%	Corrected High 5%	Clean Tons Low 5%	Clean Tons High 5%	Group	EOrd	TonsAlloc	ChProb
All non-edible food	*7.36%*	*10.95%*	*7.71%*	*11.56%*	*32,384*	*48,567*	*F16TOTMIX*	*294*	*420,098*	*0*
Tires	**0.00%**	**0.82%**	**0.00%**	**0.82%**	**0**	**3,431**	**F16TOTMIX**	**284**	**420,098**	**46**
Automotive Tires	0.00%	0.82%	0.00%	0.82%	0	3,431	F16TOTMIX	69	420,098	0
Other tires	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	70	420,098	0
Other rubber products	0.34%	1.28%	0.34%	1.30%	1,439	5,460	F16TOTMIX	71	420,098	0
Disposable diapers	4.82%	6.99%	4.82%	7.00%	20,253	29,416	F16TOTMIX	62	420,098	0
Carpet, Rugs, fiber pads	**1.10%**	**2.87%**	**1.03%**	**2.66%**	**4,339**	**11,181**	**F16TOTMIX**	**285**	**420,098**	**0**
Carpet	0.52%	1.84%	0.48%	1.73%	2,023	7,266	F16TOTMIX	65	420,098	0
Rugs	0.26%	1.16%	0.23%	1.05%	979	4,415	F16TOTMIX	66	420,098	0
Other carpet/rug pad	0.03%	0.23%	0.03%	0.23%	109	947	F16TOTMIX	68	420,098	0
Textiles & mixed	**3.19%**	**7.63%**	**2.50%**	**6.20%**	**10,504**	**26,031**	**F16TOTMIX**	**240**	**420,098**	**0**
Other textiles	2.56%	6.89%	1.99%	5.68%	8,371	23,878	F16TOTMIX	63	420,098	0
Mixed textile / material	0.51%	0.79%	0.40%	0.65%	1,701	2,729	F16TOTMIX	64	420,098	0
Asphalt roofing & tarpaper	**0.00%**	**0.16%**	**0.00%**	**0.16%**	**1**	**652**	**F16TOTMIX**	**241**	**420,098**	**21**
Asphalt roofing - recyclable	0.00%	0.16%	0.00%	0.16%	0	652	F16TOTMIX	72	420,098	0
Asphalt roofing - nonrecyclable	0.00%	0.00%	0.00%	0.00%	0	2	F16TOTMIX	73	420,098	0
Furniture + Mattresses	**0.29%**	**2.45%**	**0.29%**	**2.41%**	**1,205**	**10,128**	**F16TOTMIX**	**286**	**420,098**	**0**
Matresses & box springs	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	74	420,098	0
Furniture (mixed material)	*0.29%*	*2.45%*	*0.29%*	*2.41%*	*1,205*	*10,128*	*F16TOTMIX*	75	420,098	0
Other miscellaneous organics	**0.63%**	**1.48%**	**0.70%**	**1.71%**	**2,930**	**7,200**	**F16TOTMIX**	**242**	**420,098**	**0**
Paper composite ceiling tiles	0.00%	0.16%	0.00%	0.15%	0	610	F16TOTMIX	76	420,098	0
Compostable other organics	0.01%	0.47%	0.01%	0.60%	51	2,521	F16TOTMIX	77	420,098	0
Non-compostable other organics	0.49%	1.17%	0.55%	1.33%	2,298	5,567	F16TOTMIX	78	420,098	0
GLASS	**1.39%**	**4.13%**	**1.40%**	**4.16%**	**5,876**	**17,485**	**F16TOTMIX**	**243**	**420,098**	**0**
Deposit beverage glass	0.20%	0.41%	0.20%	0.42%	821	1,773	F16TOTMIX	79	420,098	0
No-deposit glass containers	**0.65%**	**1.02%**	**0.65%**	**1.05%**	**2,738**	**4,393**	**F16TOTMIX**	**245**	**420,098**	**0**
Deposit beverage glass in 2018	0.05%	0.13%	0.05%	0.13%	208	525	F16TOTMIX	80	420,098	0
Other clear beverage bottles	0.09%	0.25%	0.09%	0.24%	372	1,021	F16TOTMIX	81	420,098	0
Other colored beverage bottles	0.04%	0.15%	0.04%	0.15%	183	633	F16TOTMIX	82	420,098	0
Clear container glass	0.33%	0.57%	0.33%	0.59%	1,387	2,496	F16TOTMIX	83	420,098	0
Colored container glass	0.02%	0.06%	0.03%	0.08%	110	333	F16TOTMIX	84	420,098	0
Window and other glass	**0.25%**	**3.12%**	**0.25%**	**3.14%**	**1,064**	**13,184**	**F16TOTMIX**	**246**	**420,098**	**0**
Flat window glass	0.00%	2.96%	0.00%	2.97%	3	12,491	F16TOTMIX	85	420,098	0
Total fluorescents	**0.00%**	**0.01%**	**0.00%**	**0.01%**	**6**	**58**	**F16TOTMIX**	**247**	**420,098**	**2**
Fluorescent tubes	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	86	420,098	0
Compact fluorescent lights	0.00%	0.01%	0.00%	0.01%	6	58	F16TOTMIX	87	420,098	0
Other nonrecyclable glass	0.15%	0.77%	0.16%	0.77%	654	3,240	F16TOTMIX	88	420,098	0
Glass Beverage bottles	*0.44%*	*0.87%*	*0.44%*	*0.87%*	*1,837*	*3,663*	*F16TOTMIX*	*244*	*420,098*	*0*
METAL	**4.75%**	**7.13%**	**4.45%**	**6.97%**	**18,698**	**29,269**	**F16TOTMIX**	**248**	**420,098**	**0**
Aluminum	**0.34%**	**0.53%**	**0.23%**	**0.40%**	**967**	**1,664**	**F16TOTMIX**	**249**	**420,098**	**0**
Aluminum beverage cans	**0.14%**	**0.18%**	**0.12%**	**0.16%**	**498**	**686**	**F16TOTMIX**	**251**	**420,098**	**0**
Deposit aluminum bev. cans	0.12%	0.17%	0.10%	0.15%	436	617	F16TOTMIX	89	420,098	0
Deposit Alum. In 2018	0.01%	0.02%	0.01%	0.02%	45	87	F16TOTMIX	90	420,098	0
Other Aluminum bev. cans	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	91	420,098	0
Aluminum foil / food trays	0.15%	0.24%	0.06%	0.12%	258	522	F16TOTMIX	92	420,098	0
Other aluminum	**0.02%**	**0.16%**	**0.02%**	**0.15%**	**65**	**635**	**F16TOTMIX**	**250**	**420,098**	**0**
Other Aluminum curbside OK	0.02%	0.15%	0.01%	0.14%	55	599	F16TOTMIX	93	420,098	0
Large Aluminum not curbside OK	0.00%	0.01%	0.00%	0.01%	7	45	F16TOTMIX	94	420,098	0
Other nonferrous metal	**0.01%**	**0.07%**	**0.02%**	**0.07%**	**63**	**288**	**F16TOTMIX**	**254**	**420,098**	**0**
Nonferrous Metal curbside-OK	0.00%	0.02%	0.00%	0.02%	11	81	F16TOTMIX	99	420,098	0
Nonferrous Metal not curbside-OK	0.01%	0.06%	0.01%	0.06%	31	245	F16TOTMIX	100	420,098	0
Steel (tinned) cans	**0.61%**	**1.02%**	**0.55%**	**0.99%**	**2,322**	**4,142**	**F16TOTMIX**	**253**	**420,098**	**0**
Steel beverage cans	**0.00%**	**0.02%**	**0.00%**	**0.02%**	**17**	**79**	**F16TOTMIX**	**252**	**420,098**	**0**
Steel/Bimetal Deposit Cans	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	95	420,098	0
Steel/Bimetal Deposit 2018	0.00%	0.02%	0.00%	0.01%	6	56	F16TOTMIX	96	420,098	0
Steel/Bimetal Other Bev. Cans	0.00%	0.01%	0.00%	0.01%	0	39	F16TOTMIX	97	420,098	0
Other steel cans	0.61%	1.01%	0.54%	0.97%	2,278	4,094	F16TOTMIX	98	420,098	0
White goods	0.00%	0.44%	0.00%	0.44%	0	1,835	F16TOTMIX	103	420,098	0
Used oil filters	0.00%	0.01%	0.00%	0.01%	0	56	F16TOTMIX	104	420,098	0
Empty aerosol cans	0.06%	0.14%	0.06%	0.13%	252	535	F16TOTMIX	105	420,098	0
Other ferrous metal	**0.73%**	**1.39%**	**0.74%**	**1.40%**	**3,113**	**5,893**	**F16TOTMIX**	**255**	**420,098**	**0**
Other ferrous metal curb-OK	0.48%	1.04%	0.49%	1.05%	2,066	4,425	F16TOTMIX	101	420,098	0
Other ferrous metal not curb-OK	0.13%	0.51%	0.13%	0.51%	547	2,155	F16TOTMIX	102	420,098	0
Mixed ferrous/non-ferrous	**0.03%**	**0.20%**	**0.03%**	**0.20%**	**130**	**852**	**F16TOTMIX**	**256**	**420,098**	**1**
Mixed ferrous/non-ferr. curb-OK	0.00%	0.12%	0.00%	0.12%	3	492	F16TOTMIX	106	420,098	0
Mixed ferrous/non-ferr. not curb-OK	0.00%	0.13%	0.00%	0.13%	12	526	F16TOTMIX	107	420,098	0
Mixed Metal / Material	0.84%	1.92%	0.61%	1.76%	2,574	7,381	F16TOTMIX	108	420,098	0
Computers, brown goods, small apl.	**1.11%**	**2.76%**	**1.17%**	**2.93%**	**4,927**	**12,315**	**F16TOTMIX**	**260**	**420,098**	**0**
Computers & monitors	**0.00%**	**0.04%**	**0.00%**	**0.04%**	**0**	**166**	**F16TOTMIX**	261	420,098	120
Computers CPU Units	0.00%	0.04%	0.00%	0.04%	0	166	F16TOTMIX	110	420,098	0
Computer monitor CRTs	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	109	420,098	0
TVs, other CRTs, brown goods	**0.74%**	**2.17%**	**0.77%**	**2.22%**	**3,253**	**9,321**	**F16TOTMIX**	**262**	**420,098**	**0**
TVs	0.05%	1.34%	0.05%	1.34%	219	5,630	F16TOTMIX	113	420,098	0
Printers	0.06%	0.72%	0.06%	0.72%	242	3,018	F16TOTMIX	111	420,098	0
Computer mice+keyboards	0.00%	0.02%	0.00%	0.02%	3	95	F16TOTMIX	112	420,098	0
Microwaves	0.00%	0.43%	0.00%	0.43%	0	1,817	F16TOTMIX	114	420,098	0
Other consumer elect./brown goods	0.07%	0.30%	0.09%	0.44%	378	1,850	F16TOTMIX	115	420,098	0
Small Appliances-non electronic	0.08%	0.96%	0.09%	1.10%	383	4,625	F16TOTMIX	116	420,098	0
Total ferrous	*1.75%*	*2.61%*	*1.69%*	*2.58%*	*7,119*	*10,833*	*F16TOTMIX*	*258*	*420,098*	*0*
Total non-ferrous	*0.41%*	*0.63%*	*0.30%*	*0.50%*	*1,262*	*2,102*	*F16TOTMIX*	*259*	*420,098*	*0*
Recycl. metal excl. electronics, sm. apl.	*2.22%*	*3.17%*	*2.06%*	*3.01%*	*8,657*	*12,657*	*F16TOTMIX*	*257*	*420,098*	*0*
OTHER INORGANICS	**3.69%**	**6.55%**	**3.79%**	**6.70%**	**15,923**	**28,147**	**F16TOTMIX**	**263**	**420,098**	**0**
Rock, dirt, litter	2.62%	5.02%	2.69%	5.18%	11,298	21,763	F16TOTMIX	268	420,098	0
Rock, brick, dirt	0.47%	1.57%	0.50%	1.80%	2,118	7,546	F16TOTMIX	267	420,098	0
Rock, concrete, brick	0.07%	0.43%	0.07%	0.44%	301	1,845	F16TOTMIX	117	420,098	0
Soil, sand, dirt	0.27%	1.37%	0.30%	1.59%	1,260	6,659	F16TOTMIX	118	420,098	0
Pet litter, animal feces	1.69%	3.84%	1.69%	3.84%	7,093	16,114	F16TOTMIX	119	420,098	0
Gypsum wallboard	**0.06%**	**0.37%**	**0.05%**	**0.36%**	**231**	**1,524**	**F16TOTMIX**	**269**	**420,098**	**0**
Gypsum wallboard NEW	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	120	420,098	0
Gypsum wallboard OLD	0.06%	0.37%	0.05%	0.36%	231	1,524	F16TOTMIX	121	420,098	0
Fiberglass Insulation	0.04%	0.49%	0.04%	0.47%	156	1,979	F16TOTMIX	122	420,098	0
Other miscellaneous inorganics	0.34%	1.64%	0.34%	1.65%	1,427	6,942	F16TOTMIX	123	420,098	0
"MEDICAL WASTES"	0.49%	2.08%	0.49%	2.08%	2,047	8,721	F16TOTMIX	124	420,098	0

Statewide Mixed Route Trucks

Material	Field Low 5%	Field High 5%	Corrected Low 5%	Corrected High 5%	Clean Tons Low 5%	Clean Tons High 5%	Group	EOrd	TonsAlloc	ChProb
HAZARDOUS MATERIALS	**0.18%**	**0.65%**	**0.18%**	**0.67%**	**760**	**2,811**	**F16TOTMIX**	**270**	**420,098**	**0**
Lead-acid batteries	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	125	420,098	0
Dry-cell batteries	0.02%	0.08%	0.02%	0.09%	96	392	F16TOTMIX	126	420,098	0
Latex paint	0.01%	0.48%	0.01%	0.48%	24	2,007	F16TOTMIX	127	420,098	0
Oil paints	0.00%	0.01%	0.00%	0.01%	0	36	F16TOTMIX	128	420,098	0
Motor oil	0.00%	0.01%	0.00%	0.01%	0	28	F16TOTMIX	129	420,098	0
Other flammables	0.00%	0.01%	0.00%	0.01%	0	57	F16TOTMIX	130	420,098	0
Pesticides / herbicides	0.00%	0.01%	0.00%	0.01%	7	59	F16TOTMIX	131	420,098	0
Corrosive cleaners	0.00%	0.04%	0.00%	0.04%	9	147	F16TOTMIX	132	420,098	0
Asbestos	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	133	420,098	0
Mercury-containing items	0.00%	0.00%	0.00%	0.00%	0	0	F16TOTMIX	134	420,098	0
Ammunition and fireworks	0.00%	0.03%	0.00%	0.03%	0	127	F16TOTMIX	135	420,098	0
Compressed gas cylinders	0.00%	0.01%	0.00%	0.01%	0	51	F16TOTMIX	136	420,098	0
Other hazardous chemicals	0.02%	0.08%	0.02%	0.08%	69	337	F16TOTMIX	137	420,098	0
Unknown hazardous chemicals	0.00%	0.04%	0.00%	0.04%	12	176	F16TOTMIX	138	420,098	0
Total packaging	*21.56%*	*27.09%*	*16.90%*	*22.40%*	*70,995*	*94,095*	*F16TOTMIX*	272	420,098	0
Total products	*44.66%*	*52.40%*	*38.00%*	*45.35%*	*159,644*	*190,505*	*F16TOTMIX*	273	420,098	0
Total non-manufactured	*24.46%*	*30.02%*	*25.62%*	*31.32%*	*107,617*	*131,580*	*F16TOTMIX*	*274*	*420,098*	*0*
Total organic	*84.41%*	*88.21%*	*74.09%*	*77.97%*	*311,260*	*327,558*	*F16TOTMIX*	*275*	*420,098*	*0*
Total non-organic	*11.79%*	*15.59%*	*11.66%*	*15.52%*	*48,965*	*65,179*	*F16TOTMIX*	*276*	*420,098*	*0*
Compostable	*53.82%*	*60.57%*	*48.81%*	*55.79%*	*205,050*	*234,372*	*F16TOTMIX*	*277*	*420,098*	*0*
Compostable-target	*31.29%*	*38.35%*	*29.19%*	*35.86%*	*122,621*	*150,661*	*F16TOTMIX*	*278*	*420,098*	*0*
Curbside recyclables	*14.64%*	*19.68%*	*11.86%*	*16.86%*	*49,814*	*70,832*	*F16TOTMIX*	*279*	*420,098*	*0*
Recoverable (recycl., compost, energy)	*62.24%*	*67.73%*	*55.22%*	*60.91%*	*231,989*	*255,889*	*F16TOTMIX*	*280*	*420,098*	*0*
Recyclable (incl. energy, not compost)	*32.30%*	*38.13%*	*27.51%*	*33.15%*	*115,561*	*139,270*	*F16TOTMIX*	*281*	*420,098*	*0*
Compostable but not recyclable	*26.88%*	*32.83%*	*24.75%*	*30.79%*	*103,978*	*129,337*	*F16TOTMIX*	*282*	*420,098*	*0*
Not recoverable (inverse of recoverable)	*32.27%*	*37.76%*	*28.87%*	*34.30%*	*121,285*	*144,081*	*F16TOTMIX*	*283*	*420,098*	*0*
Water and Residue (Contamination)	*0.00%*	*0.00%*	*9.15%*	*11.71%*	*38,428*	*49,179*	*F16TOTMIX*	*150*	*420,098*	*0*
Supermix & fines	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0*	*0*	*F16TOTMIX*	*271*	*420,098*	*0*
Supermix	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0*	*0*	*F16TOTMIX*	*139*	*420,098*	*0*
Fines	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0*	*0*	F16TOTMIX	*140*	*420,098*	*0*

Exhibit 3

Adjacent Parcels



P:\320-000\322-142\-CADD\Dwg\SW01\322142-SW01-2-Benton County Tax Lots Exhibit.dwg{29} LS:(1/22/2025 - jshah) - LP: 7/15/2025 9:25 AM

Civil & Environmental Consultants, Inc.

2356 Gold Meadow Way
Suite 120
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VALLEY LANFDFILLS, INC.
COFFIN BUTTE LANDFILL
CONDITIONAL USE PERMIT APPLICATION
CORVALLIS, OR 97330

ADJACENT PROPERTIES FOR LITTER CONTROL

DRAWN BY:	JS	CHECKED BY:	JAS	APPROVED BY:	JAS	FIGURE NO.:	Exhibit 5
DATE:	JULY. 2025	DWG SCALE:	AS SHOWN	PROJECT NO:	322-142		

NO.	TAX LOT NO.	OWNER NAME	CURRENT ZONING
1	104070000100	OREGON STATE GAME COMMISSION	OS
2	104070000300	R B WEBBER DEVELOPMENT LLC	EFU
3	104070000400	WILFONG TRISHA M	RR-5
4	104070000500	BURDOCK GARLAND R	RR-5
5	104070000601	RINKER TRISTA M	RR-5
6	104070000700	CLEARY BRYCE LAWRENCE	RR-5
7	104070000800	SCOTT DARCI L	RR-5
8	104070000900	WHITE JASON BYRON & JULIE B	RR-5
10	104070001100	AMADOR MARIBEL	RR-5
11	104070001200	LEAVENWORTH EDYNE	RR-5
12	104080000100	OREGON STATE GAME COMMISSION	OS
13	104170000100	OREGON STATE GAME COMMISSION	OS
18	104180000100	OREGON STATE GAME COMMISSION	OS
19	104180000101	CONSUMERS POWER INC	OS
20	104180000102	BUREAU OF LAND MANAGEMENT	OS
21	104180000200	PELTIER REAL ESTATE CO	FC
22	104180000201	POWELL LYNN MAY & HEALD NATHAN LESLIE	FC
23	104180000202	GOETZINGER DALE L & MONA G	RR-5
24	104180000300	DUBIKIN ALEXANDRE & POLUSHKIN GLIKERIA	FC
25	104180000301	VALLEY LANDFILLS INC	FC
26	104180000400	DUBIKIN ALEXANDRE & POLUSHKIN GLIKERIA	RR-5
27	104180000500	YOUNG CAROLYN	RR-5
28	104180000600	YOUNG CAROLYN	RR-5
29	104180000700	HOCKEMA JOSEPH E & JASMINE L	RR-5
30	104180000701	HOCKEMA JOSEPH E & JASMINE L	RR-5
31	104180000800	OREGON STATE FISH & WILDLIFE	FC
32	104180000801	VALLEY LANDFILLS INC	FC
33	104180000900	VALLEY LANDFILLS INC	FC
34	104180001000	VALLEY LANDFILLS INC	FC
35	104180001101	VALLEY LANDFILLS INC	FC
36	104180001102	VALLEY LAND FILLS INC	FC
37	104180001103	PHILLIPS SAMUEL F & CHERYL G	FC
38	104180001104	VALLEY LANDFILLS INC	FC
39	104180001105	PELTIER REAL ESTATE CO	EFU
40	104180001106	VALLEY LANDFILLS INC	LS
41	104180001107	VALLEY LANDFILLS INC	LS
42	104180001108	VALLEY LANDFILLS INC	LS
43	104180001200	VALLEY LANDFILLS INC	FC
44	104190000100	OREGON STATE GAME COMMISSION	OS
45	104190000200	BRADLEY LOWELL THOMAS & MARY ERIN	RR-10
46	104190000301	HOLDORF CATHERINE E, TR	EFU
47	104190000400	TAMPICO RIDGE LLC	RR-10
48	104190000402	KIPPER ROBERT J & JULIE A, TR	RR-10
49	104190000500	GEIER JOEL E & REBECCA S SHERMAN	RR-10
50	104190000600	CRESS MERRILL	RR-10
51	104190000700	MORRELL JEFFREY J & PATRICIA D	RR-10
52	104190001700	CLAPP CYNTHIA R	EFU & RR-10
53	104190001800	KEN & SARAH EDWARDSSON RL TRUST	EFU
54	104190001801	SLABAUGH ROGER L & MICHELLE V	EFU
55	104190001900	HERNANDEZ VICTOR	EFU
56	10419B000300	PELTIER REAL ESTATE CO	RR-10
57	10419B000400	CARLIN KATHERYN L, TR	RR-10
58	10419B000500	FRAZIER STEVEN & DAVIS LUE ANN	RR-10
59	10419B000600	GIBBS LANCE A	RR-10
60	10419B001200	BARBARA FICK LIVING TRUST	RR-10
61	10419B001300	BARBARA FICK LIVING TRUST	RR-10
62	10419B001301	VALLEY LANDFILLS INC	RR-10
63	10419B001500	CATHERINE E HOLDORF LIVING TRUST	RR-10
64	10419B001600	VALLEY LANDFILLS INC	RR-10
65	10419D000100	POSTLEWAIT JACOB EDWARD & ELIZABETH REGA	RR-10
66	10419D000200	HOLMES RICHARD H & CHARLCY L	RR-10
109	10419DD03700	YANEZ ERIC & BETHANY J	RR-5
110	10419DD03800	LOPEZ OMAR GENARO	RR-5
111	10419DD03900	ANTONIO & ELIZABETH AMANDI REVOCABLE LIV	RR-5
112	10419DD04000	ANTONIO & ELIZABETH AMANDI REVOCABLE LIV	RR-5
119	104200000300	OREGON STATE GAME COMMISSION	OS
339	105130000100	R B WEBBER DEVELOPMENT LLC	EFU
340	105130000200	DAVID & DEBRA HACKLEMAN TRUST	FC
341	105130000201	DAVID & DEBRA HACKLEMAN TRUST	FC
342	105130000202	BERKLUND HARRISUE, TR	FC
343	105130000203	BERKLUND HARRISUE, TR	FC
344	105130000300	DENOMA JOHN T JR & SEARS DONNA J	FC
345	105130000301	SEARS ROLLIN & DONNA JEANNE	FC
346	105130000400	BRISKEY JOINT REVOCABLE LIVING TRUST	FC
347	105130000500	DAVID A PLANT TRUST	EFU
348	105130000501	MARCUM DONALD R JR	EFU
349	105130000502	LINDSEY RICHARD T & KAREN J	EFU
350	105130000600	WINN TERRILL JAMES & APRIL DOVE	EFU
351	105130000601	GOETZINGER DALE L & MONA G	EFU
352	105130000700	OSC	FC
353	105130000800	VALLEY LANDFILLS INC	EFU
354	105130000900	VALLEY LANDFILLS INC	EFU
355	105130000901	VALLEY LANDFILLS INC	EFU
356	105130000902	VALLEY LANDFILLS INC	EFU
357	105130001000	VALLEY LANDFILLS INC	LS
361	105140000105	HARLAN ANNE M	EFU
362	105140000107	EDWARD L PORTZ & JOANN PORTZ TRUST	EFU
365	105140000111	HARLAN ANNE M	EFU
385	105140001400	BUCKOVIC FAMILY TRUST	EFU
411	105230000100	OREGON STATE BOARD HIGHER ED	FC
412	105240000101	JOHNSON DEBORA LEE, TR	EFU
413	105240000102	JOHNSON DEBORA LEE, TR	EFU
414	105240000103	VALLEY LANDFILLS INC	EFU
415	105240000104	LABRASSEUR GEORGE F & YOLANDE	EFU
416	105240000105	MASON FAMILY LIVING TRUST	EFU
417	105240000106	HOLDORF CATHERINE E, TR	EFU
418	105240000190	STAHL DEE M & WAYNE A	EFU
419	105240000200	VALLEY LANDFILLS INC	EFU
420	105240000300	OREGON STATE BOARD HIGHER ED	FC
421	105240000400	FLAK TIMOTHY A & LIND GINA M	RR-10
437	104190000401	SEARLS JAMES CLUETT	RR-10

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CONDITIONAL USE PERMIT APPLICATION
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ADJACENT PROPERTIES FOR LITTER CONTROL

DRAWN BY:	JS	CHECKED BY:	JAS	APPROVED BY:	JAS	FIGURE NO.:	Exhibit 29A
DATE:	JULY. 2025	DWG SCALE:	AS SHOWN	PROJECT NO:	322-142		

Exhibit 4

Hinkle and Polette (1999)

U.S. Department of the Interior
U.S. Geological Survey

Arsenic in Ground Water of the Willamette Basin, Oregon

Water-Resources Investigations Report 98–4205

Prepared in cooperation with
OREGON WATER RESOURCES DEPARTMENT

U.S. Department of the Interior
U.S. Geological Survey

Arsenic in Ground Water of the Willamette Basin, Oregon

BY STEPHEN R. HINKLE AND DANIAL J. POLETTE

Water-Resources Investigations Report 98–4205

Prepared in cooperation with
OREGON WATER RESOURCES DEPARTMENT

Portland, Oregon: 1999

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
10615 South East Cherry Blossom Drive
Portland, Oregon 97216
E-mail: info-or@usgs.gov

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286
E-mail: infoservices@usgs.gov

Information regarding the Willamette Ground-Water Project is available at:
<http://wwworegon.wr.usgs.gov/projs_dir/willgw/willpage.html>

Information regarding Oregon District activities is available at:
<http://oregon.usgs.gov/>

CONTENTS

PLATE

FIGURES

TABLES

Acknowledgments

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Arsenic in Ground Water of the Willamette Basin, Oregon

By Stephen R. Hinkle *and* Danial J. Polette

SUMMARY AND CONCLUSIONS

Arsenic concentrations exceeding the U.S. Environmental Protection Agency (USEPA) current Maximum Contaminant Level (MCL) of 50 µg/L (micrograms per liter) are widespread in ground water in the Willamette Basin. The Oregon Water Resources Department and the U.S. Geological Survey began a cooperative study in the Willamette Basin in 1996. One goal of this study is to characterize the regional distribution of naturally occurring poor-quality ground water, such as ground water with high concentrations of arsenic. Characterization of the regional distribution of arsenic concentrations in the Willamette Basin will be useful to public health officials, water-resource managers, the medical community, and those using ground water for drinking and cooking.

The spatial distribution of arsenic concentrations in ground water of the Willamette Basin was assessed by combining historical data from 597 sites with data from 131 sites collected for this study. A total of 728 spatially distinct samples thus were available. Additional data also were collected to evaluate temporal variability of arsenic concentrations on a seasonal timescale. Samples were collected quarterly from 17 sites for 1 year for this purpose. Temporal variability was addressed for two reasons: First, characterization of temporal variability allowed evaluation of the acceptability of combining arsenic-concentration data collected during different seasons for determining the spatial distribution of arsenic concentrations. Second, knowledge of temporal variability will benefit well owners and water managers who require guidance on timing for sampling.

During the course of quarterly sampling, arsenic concentrations in water from many wells remained essentially constant, but variations of up to almost a factor of three were observed in other wells. No obvious correlation with season was apparent. Analytical accuracy, as determined from 11 standard reference samples submitted during the course of project work, generally was within ±10 percent, and always ±20 percent. Thus, analytical variability can only explain some of the observed temporal variability. One possible explanation for observed temporal variability in arsenic concentrations is that differences in the amount of pumpage prior to sampling may lead to variations in the amounts of water pumped from different sources (different aquifers or parts of aquifers), and thus, differences in water chemistry.

For a regional assessment of arsenic concentrations in ground water, where arsenic concentrations may vary in space by several orders of magnitude, the relatively smaller temporal variations such as those observed in the quarterly samples are not a significant limitation, and the aggregation of data collected at different times is justified. However, this conclusion may not necessarily apply to all investigations of arsenic concentrations in ground water. For some purposes, site-specific characterization may require characterization of temporal variability. Such characterization may require evaluation over a range of well uses and seasons.

Concentrations of arsenic in the 728 spatially distributed samples ranged from less than 1 to 2,000 µg/L. Concentrations in 58 (8.0 percent) of the samples exceeded the USEPA current MCL.

Regionally, the distribution of arsenic concentrations in ground water of the Willamette Basin appears to be primarily related to aquifer geology. High arsenic concentrations (concentrations exceeding the USEPA current MCL) are widespread in bedrock areas in south-central and eastern Lane County, and Linn County. High concentrations of arsenic also are present in some ground water in the Tualatin Basin (a subbasin in the northwestern part of the Willamette Basin). High arsenic concentrations in Lane and Linn Counties appear to be associated with two regionally extensive associations of rocks, (1) the Fisher and Eugene Formations and correlative rocks, and (2) the undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt. (These rock associations are defined by Walker and MacLeod, 1991. The undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt are approximately equivalent to the Little Butte Volcanic Series of Peck and others, 1964.) At land surface, these two rock associations cover 24 percent of the Willamette Basin. These associations of rocks include extensive volumes of silicic (rhyolitic) volcanic rocks, which are commonly associated with high concentrations of arsenic. High concentrations in the Tualatin Basin are associated with alluvial deposits. At a regional scale, well depth does not appear to be a useful predictor of arsenic concentration in the Willamette Basin. However, depth may be an important parameter on a local scale, particularly where wells of different depth tap aquifers in different geologic units.

Ground waters in bedrock areas in south-central and eastern Lane County, bedrock areas in Linn County, and alluvial areas in the Tualatin Basin may be more likely to yield water high in arsenic than ground water elsewhere in the basin. However, it cannot be assumed that these areas are the only areas in the basin that contain ground water with high concentrations of arsenic. Little or no data exist for many parts of the basin. Even in areas that have been sampled, geohydrologic heterogeneity makes it difficult to formulate meaningful generalizations regarding the likelihood of finding high-arsenic ground water. There is no substitute for actual sampling.

Available information, in combination with an understanding of processes known to promote arsenic mobilization, is sufficient to formulate hypotheses that explain arsenic sources and mobilization in the Willamette Basin. However, available geochemical data and interpretations are sparse. Thus, these hypotheses are preliminary, serving mainly to help direct future geochemical investigation in the Willamette Basin.

Anthropogenic sources of arsenic can be significant in some settings. Arsenical pesticides such as lead arsenate have been used in the basin, and arsenic can be released into the environment from industrial sources. However, regional patterns of arsenic occurrence in Willamette Basin ground water are not consistent with either industrial or agricultural sources of arsenic.

Naturally occurring arsenic commonly is found in a variety of solid phases. Arsenic can be a component of volcanic glass in volcanic rocks of rhyolitic to intermediate composition, adsorbed to and coprecipitated with metal oxides (especially iron oxides), adsorbed to clay-mineral surfaces, and associated with sulfide minerals and organic carbon. Examination of these potential arsenic sources for arsenic availability in the Willamette Basin apparently has never been done.

Two categories of processes largely control arsenic mobility in aquifers: (1) adsorption and desorption reactions and (2) solid-phase precipitation and dissolution reactions. Arsenic adsorption and desorption reactions are influenced by changes in pH, occurrence of redox (reduction/oxidation) reactions, presence of competing anions, and solid-phase structural changes at the atomic level. Solid-phase precipitation and dissolution reactions are controlled by solution chemistry, including pH, redox state, and chemical composition.

Several species of arsenic occur in nature, but arsenate (arsenic V) and arsenite (arsenic III) are the two forms commonly found in ground water. For this study, samples from five domestic wells were analyzed for arsenic species. Two additional analyses for arsenic species in ground water from the Willamette Basin were available in the literature. Arsenite was the predominant species of arsenic in six of these seven samples. The predominance of arsenite has both geochemical and toxicological implications. From a geochemical standpoint, mobility of arsenite differs from that of arsenate. From a public-health perspective, arsenite is more toxic than arsenate, and arsenite also is more difficult to remove from drinking-water supplies than is arsenate. Seven samples do not characterize regional arsenic speciation patterns. However, if the predominance of arsenite in Willamette Basin samples is substantiated by additional speciation work, public health officials and water managers may need to evaluate the scope of the arsenic problem with regard not only to arsenic concentrations, but also to arsenic speciation.

Existing data, including the speciation data, and published interpretations were used to establish preliminary hypotheses for the evolution of high-arsenic ground water in the Willamette Basin. For ground water in bedrock areas of Lane and Linn Counties, existing information suggests that at least some of the following controlling factors likely are important in adsorption and desorption reactions that often control arsenic mobility: (1) high pH, (2) presence of competing anions, and (3) occurrence of reducing conditions. Existing information did not allow for evaluation of the potential importance of adsorption and desorption reactions related to solid-phase structural changes at the atomic level, or solid-phase precipitation and dissolution reactions.

For alluvial ground water of the Tualatin Basin, presence of competing anions and occurrence of reducing conditions may be important controlling factors in arsenic adsorption and desorption reactions. These two factors might be more important than pH controls over arsenic adsorption and desorption. Reducing conditions and high concentrations of dissolved iron also suggest that dissolution of iron oxides, with subsequent release of adsorbed and (or) coprecipitated arsenic, may play a role in arsenic mobility in the Tualatin Basin.

Although the regional distribution of arsenic concentrations in ground water of the Willamette Basin has been evaluated by this study, an understanding of how ground water in parts of the basin evolved to contain high concentrations of arsenic has not yet been developed. Limited geochemical data have allowed establishment of preliminary hypotheses to explain the evolution of high-arsenic ground water. Developing an understanding of arsenic sources and processes responsible for evolution of high concentrations of arsenic, though, will require additional geochemical investigation. In particular, thermodynamic evaluation of ground water chemistry and study of solid phases present in aquifers would facilitate development of an understanding of adsorption and desorption and precipitation and dissolution reactions controlling arsenic mobility in the Willamette Basin. A key benefit of detailed geochemical study of arsenic in ground water of the Willamette Basin would be increased predictability of areas likely to yield ground water with high arsenic concentrations. Such increased predictability would be likely to have transfer value beyond the Willamette Basin.

INTRODUCTION

In response to increasing demands on ground-water resources in the Willamette Basin, Oregon (fig. 1), the Oregon Water Resources Department (OWRD) and the U.S. Geological Survey (USGS) began a cooperative study of the basin's ground-water resources in 1996. This study was designed to increase the current understanding of the ground-water resource, and to better characterize the distribution of naturally occurring poor-

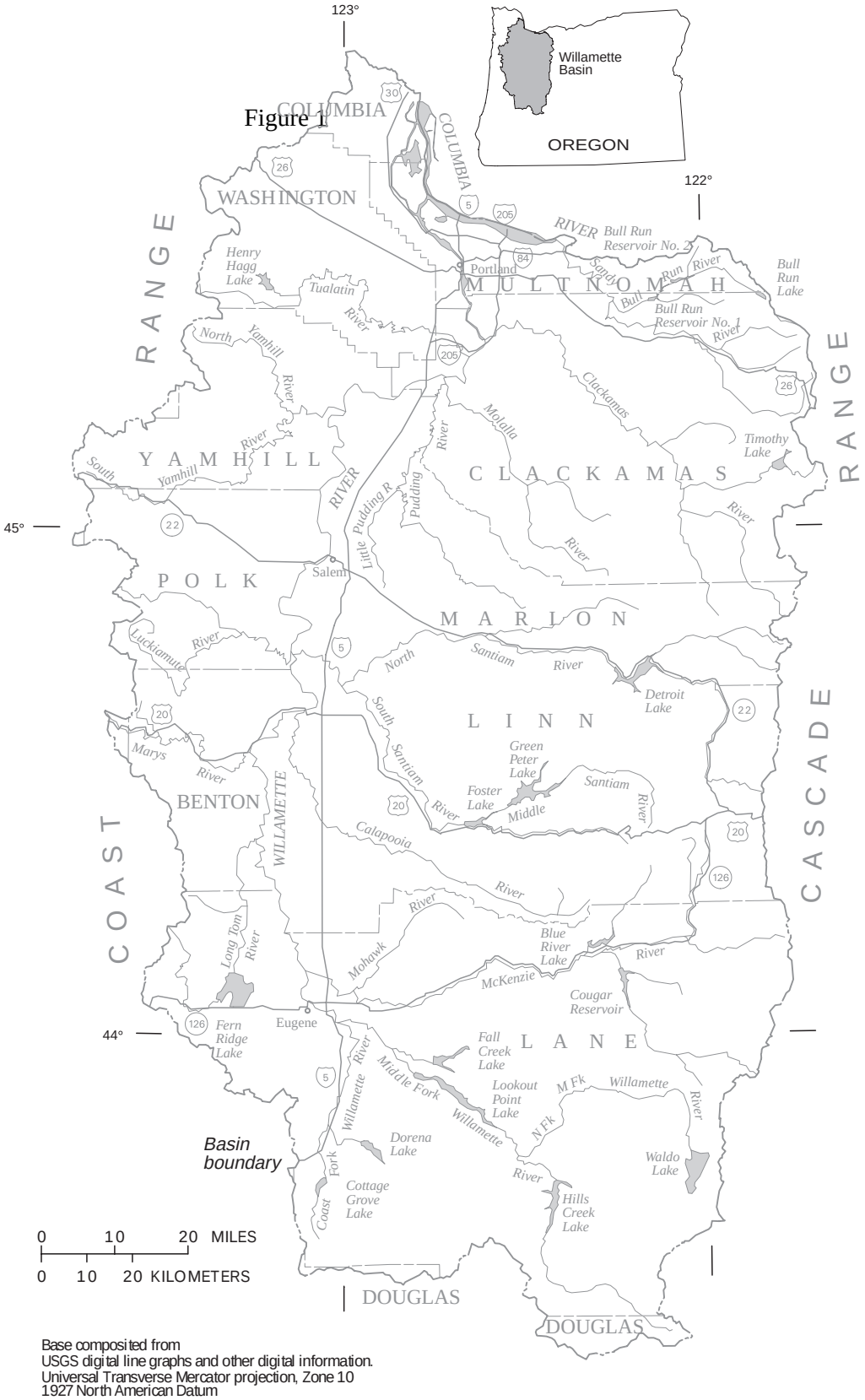

Figure 1. Location of the Willamette Basin, Oregon.

quality ground water in the basin. Essential components of the study of the physical ground-water resource are the development of a quantitative understanding of regional ground-water availability and flow, and of ground-water/surface-water interactions. Of paramount interest in the characterization of naturally occurring poor-quality ground water in the Willamette Basin is the distribution of arsenic in ground water, the subject of this report.

Arsenic contaminates many regional aquifer systems worldwide (Cantor, 1996; Thornton, 1996), and arsenic commonly is detected in ground water of the Willamette Basin at concentrations exceeding the U.S. Environmental Protection Agency (USEPA) current drinking water Maximum Contaminant Level (MCL) of 50 µg/L (micrograms per liter) (U.S. Environmental Protection Agency, 1996). Arsenic is associated with a number of adverse effects on human health. The USEPA considers arsenic to be a human carcinogen (U.S. Environmental Protection Agency, 1996). Examples of other adverse health effects attributed to consumption of arsenic range from weakness and abdominal pain to neurological and cardiovascular problems. A review of health effects associated with consumption of arsenic is given in a report by World Health Organization (1996).

Purpose and Scope

The primary purpose of this report is to describe the spatial distribution of arsenic concentrations in ground water of the Willamette Basin. Both historical data and data collected for this study (henceforth, "project data") were used for this purpose. Project data also were used to evaluate temporal variability of arsenic concentrations. It is useful to have an understanding of temporal variability before arsenic-concentration data, collected at different times, is used to evaluate spatial distributions. Evaluation of temporal variability may also benefit well owners and water managers, who may require guidance on timing for sampling.

A secondary purpose of this report is to briefly summarize current knowledge of the geochemistry of arsenic in the Willamette Basin. Relevant geochemical data are few, so this discussion is inherently general, serving mainly to outline future research needs. Possible sources of arsenic are evaluated, and geochemical processes that may control arsenic mobilization are briefly discussed.

Location and Description of the Willamette Basin

The Willamette Basin is an approximately 12,000-square-mile basin in northwestern Oregon. Primary drainage is by the Willamette River, but for the purposes of the study, the basin is defined to also include the region drained by the Sandy River; both rivers are tributary to the Columbia River. The Willamette Basin was home to 69 percent of the State's population in 1990 (Broad and Collins, 1996).

The crests of two north-south trending mountain ranges, the Coast and the Cascade Ranges, respectively define the western and eastern edges of the Willamette Basin. The Willamette Valley, an elongated, structural and erosional lowland, lies between these mountain ranges. The Coast Range is composed of marine sedimentary rocks and associated volcanic rocks. The Cascade Range is composed of lava flows and pyroclastic and epiclastic rocks. The Willamette Valley is filled with clastic basin-fill sediments of primarily alluvial origin; these alluvial sediments form the most important aquifers in the Willamette Basin. The geologic framework of the basin is described by Gannett and Caldwell (in press), and a regional representation of the surficial geology of the Willamette Basin is given on the geologic map of Oregon compiled by Walker and MacLeod (1991). Usage of geologic names in this report is consistent with that of Walker and MacLeod (1991).

STUDY DESIGN AND METHODS

The overall approach used to collect, assemble, and analyze data for this report is described in this section. First, a description of the sources of historical data is given, followed by a description of the sampling design for project data. Approaches used to define the quality of both historical and project data are discussed, as are collection and analytical methods used for project data. Finally, benchmarks for comparison of arsenic-concentration data, and methods for identification of well locations, are described.

Historical Data

Analysis of historical data (arsenic concentrations and site locations, and in most cases, well depths) from regional ground-water investigations was the starting point for evaluation of distribution of arsenic in the Willamette Basin. Some wells were sampled more than once; in these cases, the first-in-time sample was selected. Four sets of historical data used in this report are described below.

Historical data from the USGS National Water Information System (NWIS) database (Maddy and others, 1990) (271 wells). These data were collected between 1971 and 1997 as parts of various USGS projects. Many of these projects were regional in scope, and thus these data cover large areas in the Willamette Basin. In addition to arsenic concentrations, depth data also were retrieved. Data from both unfiltered and filtered samples were found in NWIS. Some of these NWIS data are discussed in the following reports: Frank and Collins, 1978; Gonthier, 1983; Leonard and Collins, 1983; Hinkle, 1997. Project data, although stored in NWIS, are discussed separately (see section "Sampling Design for Project Data").

Data from four USGS studies (Frank, 1973, 1974, 1976; Helm and Leonard, 1977), not entered into NWIS (89 wells). These data, also from regional-scale projects, encompass large areas in the southern part of the basin. The data were collected between 1964 and 1973 by USGS personnel. Well depths were obtained from tables in the reports. Techniques used to process these samples (in particular, filtering or a lack thereof) are not known.

Data from a USGS study in Lane County, not entered into NWIS (171 wells; 1 nonthermal spring). These data were collected during 1962–63, and summarized by Goldblatt and others (1963). Many of these wells withdraw water from the arsenic-rich Fisher Formation (Goldblatt and others, 1963). Arsenic concentrations and well depths were compiled from original project notes from USGS files. Samples were collected and analyzed as unfiltered samples (A.S. Van Denburgh, U.S. Geological Survey, oral commun., 1997).

Data from Linn County Department of Health Services, Environmental Health Program (65 wells). More than 100 wells were sampled for arsenic by the Environmental Health Program in 1987. Most of these wells were located near Sweet Home, an area that received little coverage in the three regional data sets listed above. Drillers' logs were on file with the Environmental Health Program for many of these wells. In 1996, USGS personnel were able to locate 65 homes corresponding to addresses from well drillers' logs for sampled wells. Arsenic concentrations from Environmental Health Program files and well depths from well drillers' logs were matched with the home locations to create a data coverage. Samples were probably collected and analyzed as unfiltered samples.

Sampling Design for Project Data

Project data were collected for several purposes. Ground-water samples were collected to fill gaps in the spatial distribution of the historical data and to illustrate the magnitude of temporal variability in arsenic concentrations. In addition, five ground-water samples were analyzed for arsenic species. Quality-control (QC) data were collected to evaluate the quality of project data, evaluate the quality of historical data (by resampling selected historical sites), and compare results obtained by different processing and analytical methods.

Samples from 125 wells and 6 nonthermal springs were collected during 1996 and 1997 to complement the spatial distribution of historical data. The wells and springs sampled were distributed throughout the lower elevation areas of the Willamette Basin, which are areas of greatest ground-water use. These sites had not previously been sampled for arsenic by the USGS. Some wells were sampled more than once during the course of this project; in these cases, the first-in-time samples were used to define the spatial distribution of arsenic.

To evaluate temporal variability of arsenic concentrations, samples were collected quarterly for 1 year from each of 17 sites. These samples also were collected during 1996 and 1997. A subset (5) of these 17 sites were sampled for arsenic species.

QC samples were used to evaluate the quality of techniques used to collect and analyze project samples. Twelve field equipment blanks, 6 sets of triplicate split samples, and 11 standard reference samples (SRSs) were analyzed over the course of the project. Field equipment blanks allow evaluation of the extent of any sample contamination

resulting from sample collection, processing, and analysis. Replicate samples allow evaluation of the reproducibility (precision) of analyses. SRSs facilitate evaluation of analytical accuracy. The USGS SRS program, an interlaboratory testing program, is described in a report by Long and Farrar (1995). Preparation, description, and most probable values (MPVs) of constituents of individual SRSs used in this study are described by U.S. Geological Survey (1990) and Long and Farrar (1991, 1993, 1995). An MPV for an analyte is the median of the concentrations determined by the participating laboratories. Analytical results are reported as percentages of SRS-program MPVs.

Additional quality assurance included resampling 11 historical sites. Comparison between historical arsenic concentrations and concentrations determined upon resampling offers a measure of the reliability of historical data.

Comparisons between filtered and unfiltered samples, and between USGS and USEPA analytical methods, also were made. Characterization of differences in arsenic concentrations among unfiltered and filtered samples helps quantify the effect of sample filtering, and increases the transfer value of the data and interpretations presented in this report. Data from comparison of USGS and USEPA analytical methods facilitate comparison of arsenic concentrations determined by USGS methods with USEPA water-quality criteria.

Project Sample Collection Methods

Project samples from wells and springs used for evaluation of spatial distribution of arsenic were not filtered. Unfiltered samples, in addition to being more economical to collect than samples filtered through 0.45-µm (micrometer) filters, also have the advantage of being more representative of the water being consumed by most well owners. Another justification for collection of unfiltered samples is that many of the historical data, with which project data were combined, were from analyses of unfiltered samples. Furthermore, USEPA and World Health Organization (WHO) guidelines for water quality (see section "Comparisons with Water-Quality Criteria") apply to "finished water." For most project wells, which were primarily domestic wells, "finished water" generally is equivalent to unfiltered water. However, because unfiltered samples may contain more colloids and (or) more sediment entrained during pumping, unfiltered samples are less representative of water actually moving through an aquifer than are 0.45-µm-filtered samples. Thus, the use of unfiltered samples in characterization of ground-water quality represents an approximation. Additional, quantitative discussion on this topic is presented in the section, "Comparison of Processing and Analytical Methods."

Of the 125 project wells used for evaluation of spatial distribution of arsenic, 116 were actively used domestic wells. The remaining 9 wells included 3 public-water-supply wells, 3 industrial wells, 2 irrigation wells, and 1 livestock well. Of these nine wells, those that were not actively used were purged a minimum of three casing volumes prior to sampling to remove standing water from the well. Samples from actively used wells were collected following a minimum purge time of 1 minute. Longer purge times, characteristic of most USGS ground-water-quality work, were deemed unnecessary for actively used wells in this project because these wells experienced a degree of regular purging from the frequent use of the wells. A resulting limitation, however, is that samples from these wells may lose arsenic by way of adsorption to iron casing or precipitation as ground water undergoes geochemical changes while residing in a well bore or casing. Thus, arsenic concentrations in samples from these wells may be biased toward low arsenic concentrations relative to water actually moving through the aquifer. The extent of this possible bias has not been quantified, but because these wells were actively used, this potential bias is likely to be small.

Project samples collected from springs were collected from flowing springs. Fine sediment was present along with the water in several of the springs, so spring samples were filtered through 0.45-µm nominal-pore-size filters.

Project wells sampled for evaluation of temporal variability in arsenic concentrations were actively used wells, sampled using the same methods as for project wells sampled for evaluation of spatial distribution of arsenic.

Project wells sampled for arsenic speciation also were actively used wells. Samples were collected as unfiltered samples following a minimum well purge time of 1 minute. Samples were col-

lected without headspace in brown glass vials, wrapped in aluminum foil (to prevent photooxidation), and shipped on ice to the laboratory.

Eleven wells represented in the historical data set were resampled. All were actively used wells and were sampled using the same methods as for project wells sampled for evaluation of spatial distribution of arsenic.

Samples for comparison between filtered and unfiltered samples, and comparison of USGS and USEPA methods, were collected from a subset of the wells sampled for temporal variability. Each 10-liter sample was split in the field by mechanical agitation into four subsamples. One subsample was filtered through a 0.10-µm nominal-pore-size 47-mm-diameter filter. One subsample was filtered through a 0.45-µm nominal-pore-size 142-mm-diameter filter. Two subsamples were collected as unfiltered samples. For each set of the four subsamples, both of the filtered samples and one of the unfiltered samples were analyzed by USGS methods (see section "Project Analytical Methods"). The other unfiltered sample was analyzed by USEPA methods (see section "Project Analytical Methods").

All arsenic samples, except samples collected for analysis of arsenic species, were field-acidified to below pH 2 with nitric acid. Samples for analysis of arsenic species were not acidified.

Project Analytical Methods

Arsenic analyses were done at the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado. Most arsenic determinations were done by hydride atomic absorption with a 3-minute sulfuric acid and potassium persulfate digestion (Fishman and Friedman, 1989). This is the standard USGS method, and it is referred to as the "USGS method" in this report. Ten analyses were done by graphite furnace atomic absorption with a 2-hour hydrochloric acid and nitric acid digestion (U.S. Environmental Protection Agency, 1994). This method is referred to as the "USEPA method" in this report. The analytical minimum reporting level (MRL) was 1 µg/L for both methods.

Samples for arsenic speciation were analyzed by the USGS Methods Research and Development Program at the USGS NWQL. Samples were analyzed for two inorganic species, arsenite (arsenic III) and arsenate (arsenic V), and two organic species, monosodium methylarsonate (CH_3AsO_3HNa) and sodium dimethylarsinate ($(CH_3)_2AsO_2Na$). Analyses were done by direct injection high-performance liquid chromatography/hydride generation/inductively coupled plasma-mass spectrometry. Method detection limits (MDLs) were 0.2 µg/L (expressed as mass of arsenic per liter). Samples were analyzed within 48 hours of collection.

Comparisons with Water-Quality Criteria

To provide benchmarks against which arsenic-concentration data can be compared, arsenic-concentration data are compared with USEPA and WHO drinking-water standards. Concentrations of arsenic are compared to the USEPA current drinking water MCL for arsenic of 50 µg/L (U.S. Environmental Protection Agency, 1996). The USEPA current MCL is the maximum concentration of a contaminant allowed in a public water system. This MCL is under review (U.S. Environmental Protection Agency, 1996). Bagla and Kaiser (1996) report that the USEPA is considering reducing the current MCL by 90 percent. However, until any such reduction in the MCL occurs, the current MCL remains a logical benchmark for comparison. As an alternative benchmark, concentrations of arsenic also are compared to the WHO provisional guideline of 10 µg/L (World Health Organization, 1996).

Water with an arsenic concentration below the USEPA current MCL or WHO provisional guideline is not necessarily free from health risks. For example, arsenic concentrations may be below the USEPA current MCL and WHO provisional guideline, but still be greater than the USEPA drinking-water Risk-Specific-Dose Health Advisory (RSDHA) of 2 µg/L (U.S. Environmental Protection Agency, 1996). (The RSDHA is defined as the concentration of a contaminant in drinking water that is expected to result in a specified increased risk of cancer. The USEPA RSDHA for arsenic is calculated at the 1-in-10,000 cancer risk level. Consumption of water containing a contaminant at the RSDHA 1-in-10,000 risk level is expected to be associated with the following risk: a 70-kg adult drinking 2 L of such water per day for 70 years faces an increased risk of cancer of

approximately 1 in 10,000.) Furthermore, effects of arsenic consumption on human health are not uniform among different people, and no single threshold can be defined as the dividing line between "safe" and "unsafe." Comparison of arsenic data to the USEPA current MCL and WHO provisional guideline are done solely for illustrative purposes; no implication of "safety" or lack thereof is implied.

Methods of Identifying Wells

All wells discussed in this report were assigned well location names corresponding to well locations. Well locations generally were determined when the wells were first visited. Well locations were identified using the Township, Range, and Section method of land subdivision. Two methods are shown on figure 2. Most wells were identified with a system that uses nested groups of the letters A, B, C, and D for section subdivision. Prior to about 1967, wells were identified with an alternative system, using letters A through R (excluding I and O) for section subdivision. To preserve linkage to historical data sources, all wells discussed in this report are referred to by the well location names originally assigned to them. It should be noted, however, that in some cases, the original well location names do not accurately describe the true locations of the wells. To provide accurate locational and identifying information for wells discussed in this report, corrected well locations, and additional identifying information (USGS site identification number and OWRD well log identification number), are listed along with original well locations in the

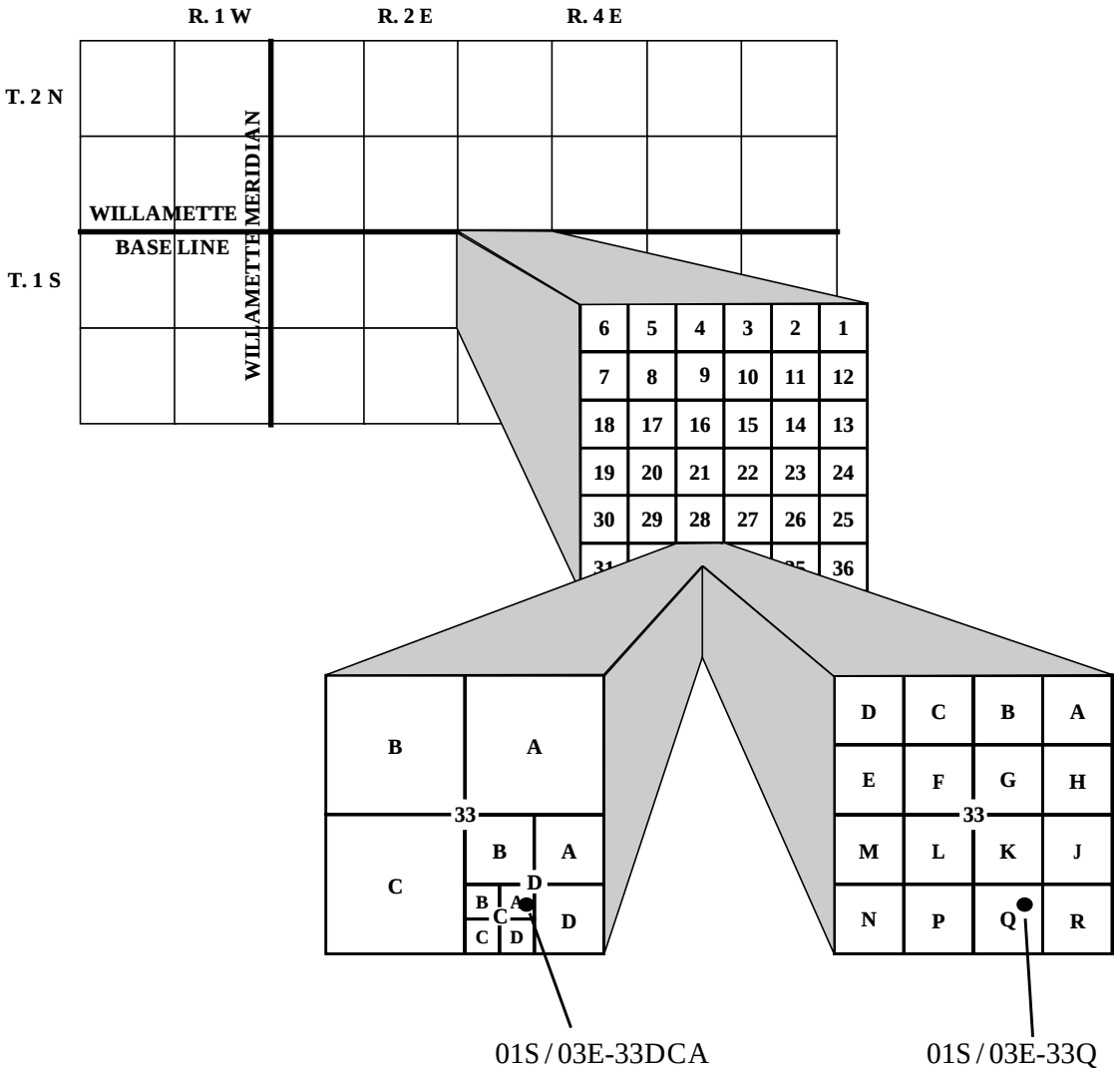

Figure 2. Well-location system.

Appendix. Note that in the project data report (Orzol and others, in press), wells are listed by corrected well location names.

DATA QUALITY: SAMPLING AND ANALYTICAL VARIABILITY VERSUS ENVIRONMENTAL VARIABILITY

In this section, project QC data are evaluated to characterize sampling and analytical variability. Sampling and analytical variability must be evaluated before environmental variability can be addressed. Three sets of QC data were collected as part of project data-collection activities. First, sampling and analytical variability of project data are evaluated. Second, the quality of historical data is discussed. Evaluation of historical data is difficult because few historical quality-control data are available. However, resampling of historically sampled sites provides insight into the quality of the historical data. Third, a comparison of sample processing and analytical methods is presented; these data illustrate the magnitude of the differences that can arise from use of various sample processing and analytical methods.

Quality of Project Data

All 12 project field equipment blanks yielded arsenic concentrations below the MRL of 1 µg/L. These results indicate that field and laboratory methods were noncontaminating.

The coefficient of variation (CV) (standard deviation divided by mean, expressed in percent) for each of the six sets of project triplicate split samples ranged from 0.0 to 14 percent. The median CV was 6.0 percent.

Analytical accuracy of project data was quantified with data from 11 SRSs. Analytical accuracy ranged from 92 to 110 percent for nine of the SRSs, but was 82 and 120 percent for the other two SRSs. In other words, reported concentrations were in error by up to about ±20 percent.

Contamination-free sampling and analysis, and reasonable analytical precision and accuracy, indicate that project data were adequate for definition of patterns of regional arsenic occurrence. However, because analytical accuracy was observed to range up to about ±20 percent, definitive characterization of temporal variability at individual sites is compromised where temporal variability also is on the order of ±20 percent or less.

Quality of Historical Data

The quality of project data is well characterized, so comparison of project and historical arsenic concentrations yields a measure of the quality of the historical data. Evaluation of the analytical accuracy of historical data is particularly desirable. However, arsenic concentrations determined in original studies and determined again during this study may differ for a variety of reasons unrelated to differences in data quality. Notably, differences between historical arsenic concentrations and arsenic concentrations determined from sampling during this project may reflect changes in the source of water being sampled at different times. Changes in the source of water being sampled can arise for a number of reasons. Ground-water flowpaths in aquifers can change over seasonal or longer time scales. Also, water often flows into wells from more than one permeable zone, and the relative contributions from different zones can change as pumping stresses change. Thus, changes in type of well use (for example, change from domestic use to lawn-watering use) or differences in the history of well use prior to sampling can result in changes in the source of water being withdrawn from wells. Finally, changes in well construction or well characteristics (for example, well cave-in over time) can result in changes in source water for wells. (Note, however, that none of the 11 wells were known to have been deepened between the time of historical sampling and the time of project resampling.) In addition to changes in source water to wells, variability in arsenic concentrations can arise from differences in sample processing prior to analysis, or, especially in the case of unfiltered samples, differences in the amount of colloid- or sediment-bound arsenic. Therefore, an absence of strong correlation between historical and project arsenic concentrations is not necessarily cause for rejection of the historical data. Because differences between historical and project data can arise from a number of factors in addition to differences in data quality, the central purpose for which the resampling data were collected was to determine if the magnitudes of the historical data are adequate

for definition of patterns of regional arsenic occurrence.

Data from the 11 sites with historical data that were resampled are presented in table 1. Differences between historical and project data are variable. For example, a difference of less than 10 percent was observed for well 19S/03W-31E1, whereas an order-of-magnitude difference was observed for well 22S/03W-17N. However, historical and project arsenic concentrations were in agreement when interpreted relative to exceedances of the USEPA current MCL. Sites at which historical arsenic concentrations exceeded the USEPA current MCL also yielded water exceeding the USEPA current MCL upon sampling during this project, and sites at which historical arsenic concentrations were less than the USEPA current MCL also yielded water below the USEPA current MCL upon sampling during this project. The historical data therefore indicate a similar pattern of spatial variability of arsenic concentrations as the project data.

Closer examination of these data indicates that data from the early 1960s generally correlate poorly with project data, whereas later data demonstrate reasonably good correlation. This pattern may reflect improvements in analytical techniques since the early 1960s.

Because two historical samples dating from the mid- to late-1960s (wells 12S/01W-29N1 and 18S/04W-14ACB) had both arsenic and chloride data, these sites were sampled for chloride as well as arsenic during project sampling (table 1). For well 12S/01W-29N1, both the arsenic and chloride concentrations were slightly lower upon project sampling: the arsenic concentration upon project sampling was 86 percent of the historical concentration, and the chloride concentration, 88 percent of the historical concentration. For well 18S/04W-14ACB, both the arsenic and the chloride concentrations were considerably lower upon project sampling: the arsenic concentration upon project sampling was 60 percent of the historical concentration, and the chloride concentration, 33 percent of the historical concentration. Historical chloride concentrations would be expected to be reliable, and would have been negligibly affected by sample processing or the presence of colloids and sediment. Thus, the changes in chloride concentrations suggest that changes in the source of water being pumped by these two wells have occurred over time. If historical chloride concentrations had been similar to project chloride concentrations, then the historical arsenic analyses might be suspect. However, differences in chloride concentrations between historical and project sampling suggest that differences in arsenic concentrations between historical and project sampling were a result, at least in part, of changes in the source of water being pumped by these wells.

Comparison of historical arsenic concentrations and arsenic concentrations determined upon project sampling indicate that historical arsenic concentrations will not necessarily reflect current arsenic concentrations. Use of historical data in process-oriented geochemical studies could be problematic. However, the comparison does

Table 1. Comparison of historical arsenic concentrations with arsenic concentrations measured during this project
[Well location as recorded in original data source; arsenic concentrations in micrograms per liter; "--", unknown]

		Historical data		Project resampling	
Source for historical data	Well location	Date	Arsenic concentration	Date	Arsenic concentration
USGS files; Goldblatt and others, 1963	18S/04W-22B	10/04/62	160	08/20/97	820
USGS files; Goldblatt and others, 1963	18S/04W-10D	10/17/62	120	08/20/97	520
USGS files; Goldblatt and others, 1963	22S/03W-17N	10/25/62	32	09/05/96	3
USGS files; Goldblatt and others, 1963	19S/03W-11E2	01/08/63	420	11/13/96	700
USGS files; Goldblatt and others, 1963	19S/03W-31E1	03/29/63	120	11/13/96	130
Frank, F.J., 1973	18S/04W-14ACB	06/12/69	500[a]	09/06/96	300[b]
Helm and Leonard, 1977	12S/01W-29N1	06/24/65	70[c]	08/29/96	60[d]
Linn County Dept. of Health Services	13S/01E-33	--/--/87	10	09/06/96	4
Linn County Dept. of Health Services	14S/01E-05	--/--/87	74	09/06/96	89
Linn County Dept. of Health Services	13S/01E-33AC	04/09/87	900	09/06/96	790
Linn County Dept. of Health Services	13S/01E-35	07/06/87	<5	09/06/96	3

[a]Chloride concentration 43 milligrams per liter.
[b]Chloride concentration 14 milligrams per liter.
[c]Chloride concentration 26 milligrams per liter.
[d]Chloride concentration 23 milligrams per liter.

suggest that the historical data are adequate for definition of patterns of regional arsenic occurrence.

Comparison of Processing and Analytical Methods

Hydrologists employ a variety of sample processing and analytical methods in geochemical and water-quality studies. Samples may be collected as unfiltered or as filtered samples. Filtering may be done using any of a variety of pore sizes, but 0.10-µm and 0.45-µm pore sizes are most commonly used. Analysis of arsenic usually is done using either hydride atomic absorption (commonly used by the USGS) or by graphite furnace atomic absorption (commonly used by the USEPA).

When combining data collected by a number of investigators using a variety of sample processing and analytical methods, questions about the comparability of data arise. Furthermore, comparison of analyses performed using non-USEPA analytical methods against USEPA water-quality criteria raises questions about comparability of analytical techniques. Information on comparability of different sample processing and analytical methods is given in this section. Data from split samples that were (1) filtered through 0.10-µm nominal-pore-size filters and analyzed by hydride atomic absorption, (2) filtered through 0.45-µm nominal-pore-size filters and analyzed by hydride atomic absorption, (3) analyzed as unfiltered samples using hydride atomic absorption, and (4) analyzed as unfiltered samples using graphite furnace atomic absorption are shown in table 2 and on figure 3.

Differences in reported arsenic concentrations between unfiltered and filtered samples generally were small. However, one set of samples (from well 21S/03E-08CBD2) demonstrated that concentrations of arsenic in unfiltered samples can be considerably greater (factor of three) than those in filtered samples. Differences between unfiltered and filtered samples may result from differences in the amount of colloid- or sediment-associated arsenic in the samples. Concentrations in both the unfiltered and the filtered samples from this site were greater than the USEPA current MCL, so interpretation was not affected significantly. However, interpretation of data from other sites could conceivably be affected by such differences between unfiltered and filtered samples and investigators will need to bear such potential differences in mind. Overall, however, combining filtered and unfiltered samples appears to be acceptable for definition of patterns of regional arsenic occurrence.

Differences in reported arsenic concentrations between the two analytical methods were small. Arsenic concentrations reported for samples analyzed by the USEPA method were slightly higher than those analyzed by the USGS method. These differences could be a result of differences in analytical methods. The longer digestion associated with the USEPA method could result in differences in reported arsenic concentrations. Different reagents used in sample digestion in the two methods also could result in differences in reported arsenic concentrations. However, the observed differences also could simply represent analytical variability.

Table 2. Comparison of arsenic concentrations for various processing and analytical methods

[USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; arsenic concentrations in micrograms per liter; processing and analytical methods described in text]

Well location	Filtered, 0.10-micrometer filter	Filtered, 0.45-micrometer filter	Unfiltered (USGS method)	Unfiltered (USEPA method)
01N/03W-04CCC	54	57	53	64
01N/03W-07CCD1	17	17	16	22
01N/03W-15ADB1	47	47	53	60
01S/03W-10BCA1	55	57	59	64
02S/02W-11CCD1	16	16	20	24
15S/01W-23CCA	18	18	18	21
17S/01W-24DCA	70	75	70	82
19S/01W-03ADB	41	43	40	46
21S/03E-08CBD2	62	64	180	180
18S/04W-14BBA	1,100	1,100	1,100	1,200

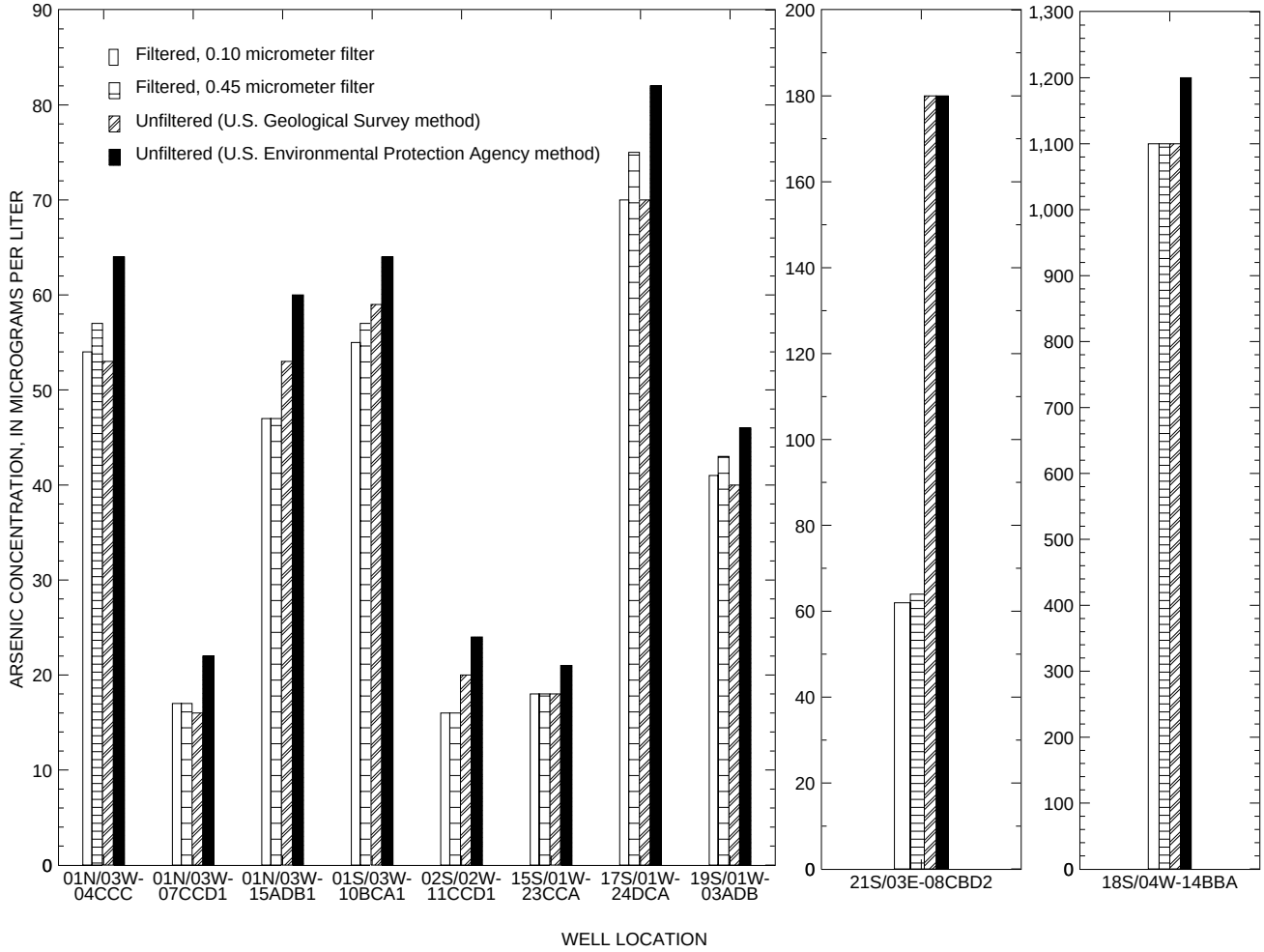

Figure 3. Comparison of arsenic concentrations determined by various processing and analytical methods.

DISTRIBUTION OF ARSENIC

The distribution of arsenic in ground water of the Willamette Basin is discussed in terms of temporal and spatial variability. First, project data are used to assess temporal variability. It is useful to assess temporal variability before arsenic-concentration data collected at different times is used to evaluate spatial distribution. Also, assessment of temporal variability should benefit well owners and water managers who desire guidance on when to sample for arsenic. Second, historical and project data are used to define spatial variability of arsenic concentrations in ground water in the Willamette Basin.

Temporal Variability

Project data were used to evaluate temporal variability of arsenic concentrations in ground water during a 1-year period. These data help characterize variability resulting from seasonal and other short- to medium-term factors. Characterization of temporal variability in arsenic concentrations over longer periods of time was not explicitly done, but long-term variability was discussed qualitatively in a previous section of this report, “Quality of Historical Data.”

Arsenic concentrations measured quarterly over a period of 1 year at 17 sites are given in table 3 and shown on figure 4. Field-measured specific conductance, a surrogate for dissolved solids, also is given in table 3. Arsenic concentrations did exhibit temporal variability. Although arsenic concentrations in water from many wells remained essentially constant over the course of sampling, concentrations at some sites varied by up to almost ±50 percent from mean concentrations, and arsenic concentrations in samples from well 19S/01W-

Table 3. Temporal variations in arsenic concentrations and specific conductance

["As", arsenic concentration in µg/L (micrograms per liter); "SC", field-measured specific conductance in µS/cm (microsiemens per centimeter) at 25 degrees Celsius; "--", not measured]

Well location	Date	As	SC	Date	As	SC	Date	As	SC	Date	As	SC	Date	As	SC
01N/03W-04CCC	11/21/96	53	587	02/20/97	52	585	05/15/97	82	496	08/19/97	97	522	12/05/97	72	616
01N/03W-07CCD1	11/19/96	16	345	02/20/97	17	357	05/15/97	19	345	08/19/97	26	314	12/05/97	18	345
01N/03W-15ADB1	11/21/96	53	1,220	02/20/97	47	1,300	05/15/97	64	1,390	08/19/97	63	1,500	12/05/97	52	1,450
01S/02W-29DBD	11/12/96	33	--	02/20/97	28	194	05/15/97	35	193	08/19/97	41	195	12/05/97	29	192
01S/02W-33BBA	11/12/96	12	--	02/20/97	10	274	05/15/97	12	272	08/19/97	13	275	12/05/97	12	274
01S/03W-10BCA1	11/19/96	59	341	02/20/97	52	340	05/15/97	62	339	08/19/97	56	339	12/05/97	56	341
02S/02W-11CCD1	11/19/96	20	335	02/20/97	16	335	05/15/97	18	334	08/19/97	19	336	12/05/97	18	336
15S/01W-23CCA	08/14/96	19	268	11/15/96	18	263	02/18/97	19	261	05/13/97	17	262	08/20/97	19	262
15S/01W-23CCC2	08/14/96	11	164	11/15/96	11	167	02/18/97	10	163	05/13/97	9	161	08/20/97	12	164
17S/01W-24DCA	09/06/96	85	194	11/15/96	70	198	02/19/97	74	195	05/13/97	84	191	08/21/97	69	193
18S/04W-14ACA	09/05/96	9	319	11/14/96	6	293	02/18/97	5	253	05/14/97	6	250	08/21/97	10	320
18S/04W-14BBA	09/04/96	830	1,040	11/15/96	1,100	1,070	02/20/97	640	797	[a]	[a]	[a]	08/20/97	1,100	1,060
19S/01W-03ADB	09/04/96	15	188	11/14/96	40	329	02/18/97	23	193	05/13/97	33	237	08/21/97	28	205
19S/03W-11E2	11/13/96	700	389	02/19/97	710	393	05/14/97	740	396	08/20/97	850	391	12/04/97	800	390
19S/03W-31E1	11/13/96	130	295	02/19/97	130	295	05/14/97	140	291	08/20/97	130	285	12/04/97	130	292
21S/03E-08CBD2	09/05/96	140	1,590	11/14/96	180	1,460	02/18/97	130	1,120	05/13/97	100	1090	09/04/97	69	1,450
22S/03W-17N	09/05/96	3	298	11/13/96	3	292	02/19/97	4	276	05/14/97	4	295	09/04/97	4	381

[a]Four samples within 37 hours:
05/13/97 at 7 p.m., As, 1100 µg/L; SC, 1090 µS/cm
05/14/97 at 10 a.m., As, 810 µg/L; SC, 952 µS/cm
05/14/97 at 8 p.m., As, 880 µg/L; SC, 809 µS/cm
05/15/97 at 8 a.m., As, 600 µg/L; SC, 877 µS/cm.

03ADB varied by a factor of 2.7 between the lowest and highest concentrations. The data as a whole demonstrate no obvious correlation with seasons. Analytical variability may be responsible for some of the observed variability, but can only explain up to about ±20-percent variation among samples. Differences in arsenic concentrations also could be due, in part, to temporally varying amounts of colloid- or sediment-bound arsenic. However, 10 of the 17 wells used for quarterly sampling also were used in the comparison of unfiltered and filtered samples. The resulting data showed little colloid- or sediment-bound arsenic present in samples from those wells at that time, except for well 21S/03E-08CBD2. Clearly, other factors are responsible for some of the observed temporal variability in arsenic concentrations.

It is likely that temporal variability in project data reflects variation in contributing sources of water to wells, and in the absence of seasonal patterns in temporal data, variation in contributing sources to wells is probably largely due to short-term (hour-to-hour or day-to-day) variations in well use prior to sampling. Relatively heavy well use can temporarily deplete water from parts of an aquifer adjacent to the well, and thus the well can yield water of different chemical quality than when sampled after a period of relatively light use. Two pieces of evidence suggest that some of the 17 wells sampled for temporal variability yield water from different sources at different times, although a relation between differences in contributing sources to wells and differences in well use remains only a hypothesis. One piece of evidence for changing water sources to wells lies in the specific conductance data. Specific conductance generally was less variable in samples where arsenic concentrations were less variable (table 3). Furthermore, specific conductance had the greatest relative temporal variability for water from well 19S/01W-03ADB; the same site also had the greatest relative temporal variability in arsenic concentrations (table 3). Because large changes in the chemistry of individual bodies of ground water generally take place over a period of years, it is difficult to explain large seasonal changes in specific conductance of well water by processes other than changing water sources to wells. A second piece of evidence suggesting changing water sources to wells is derived from examination of data from well 18S/04W-14BBA. Maximum and minimum arsenic concentrations in samples from this site varied by nearly a factor of two over the course of a year. At this site, some additional temporal sampling was conducted. Four samples were collected over one 37-hour period. The observed variability during a

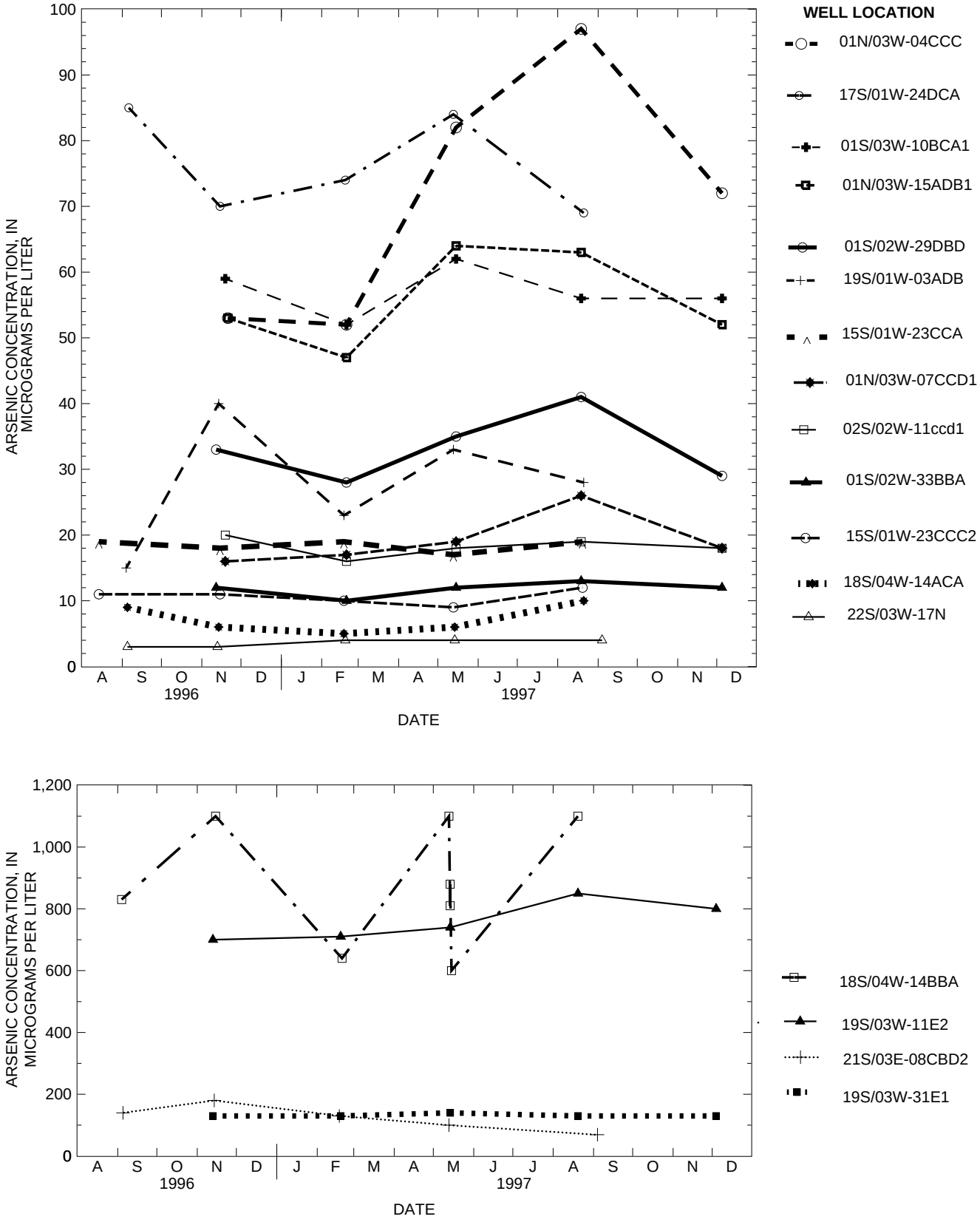

Figure 4. Temporal variations in arsenic concentrations.

37-hour period was as great as the variability observed during the course of a year (table 3, fig. 4). Such variability over the course of 37 hours cannot be ascribed to seasonal factors.

Certainly, a relationship between arsenic concentrations and well use prior to sampling remains only a hypothesis. But regardless of the processes resulting in the observed temporal variability, the data demonstrate that short-term variability in arsenic concentrations can be similar in magnitude to variability observed during the course of quarterly sampling.

The temporal variability of the project data (less than a factor of three) contrasts greatly with temporal variability in arsenic concentrations reported by Nadakavukaren and others (1984) for some wells in Lane County in the southern part of the Willamette Basin. Nadakavukaren and others (1984) reported temporal variability of up to about three orders of magnitude over the course of a year for some of the 14 wells sampled. Such variability is intriguing, because temporal variability of this magnitude in ground-water chemistry at individual sites is unusual.

Nadakavukaren and others (1984) noted that arsenic concentrations often were low (relative to mean concentrations) during the winter (rainy) season. However, they also reported that equally low concentrations were observed during other seasons, including the summer (dry) season, at several sites. Thus, although they observed temporal variability in arsenic concentrations, Nadakavukaren and others (1984) reported that they were unable to relate temporal variability to environmental factors. Unfortunately, sample-collection procedures were not defined in the paper. One aspect of the data not discussed in the original paper, but that may have significant bearing on interpretation of temporal variability, is that most of the wells sampled were irrigation wells. Irrigation wells tend to be unused during the rainy season, and frequently remain idle for long periods during other parts of the year. Recall that it was proposed that temporal variability of project data was related, at least in part, to well use prior to sampling, and recall, also, that project wells either were actively used domestic wells or were sampled after purging three well-bore volumes. It is possible that the extreme variability in arsenic concentrations reported by Nadakavukaren and others (1984) could be related to previous well use (or lack of well use), especially if the wells were not purged prior to sampling. Certainly, the use of irrigation wells for most of the work presented by Nadakavukaren and others (1984), and the absence of documentation of well-purging criteria, make interpretation of their temporal data difficult. Data of Nadakavukaren and others (1984) suggest that caution be applied when using historical data for which both well-use and well-purging information are unavailable.

The absence of seasonal trends in project data suggests that data collected at different times in the Willamette Basin can be combined for use in definition of spatial variability in arsenic concentrations. However, data of Nadakavukaren and others (1984), although difficult to interpret, suggest that historical data for which the history of well use and well purging are unknown may not always be sufficient for site-specific characterization. Thus, although temporal variability is not likely to be a significant problem for a regional evaluation of ground-water arsenic concentrations, the quality of historical data should be evaluated. Most of the historical data compiled for use in this report were from samples collected by USGS personnel. The remainder of the data (from Linn County Department of Health Services, Environmental Health Program) were collected from domestic wells, which presumably were actively used wells. USGS protocols have long required (at least as far back as 1960; Rainwater and Thatcher, 1960) that ground-water samples be collected from purged or actively used wells. Thus, from a standpoint of well use/well purging, the historical data used in this report are believed to be of adequate quality for a regional assessment of arsenic concentrations in ground water. Resampling of selected wells represented in the historical data supports this assumption, as was shown in the section “Quality of Historical Data.”

Spatial Distribution

Historical and project data were combined and used to evaluate the spatial distribution of arsenic concentrations in ground water of the Willamette Basin. A total of 728 spatially distinct samples thus were available—597 historical and 131 project samples. Of these 728 samples, 721 were from wells, and 7 were from nonthermal springs. These data are available in digital format

(CD-ROM) in a separate data report (Orzol and others, in press).

Concentrations of arsenic in the 728 samples ranged from < 1 to 2,000 µg/L. A histogram of these data is shown on figure 5. Concentrations in 58 samples (8.0 percent) exceeded the USEPA current MCL (50 µg/L), and 158 (21.7 percent) exceeded the WHO provisional guideline (10 µg/L). The 728 samples were not randomly distributed throughout the basin, so it does not follow that 8 percent of all wells in the basin will exceed the USEPA current MCL. Furthermore, because some of the data (in particular, data of Goldblatt and others, 1963, and data from Linn County Department of Health Services) were collected to address suspected arsenic problems, the cumulative data set contains a bias towards high arsenic concentrations (exceeding the USEPA current MCL). The data do, however, indicate the existence of extensive bodies of high-arsenic ground water in the basin.

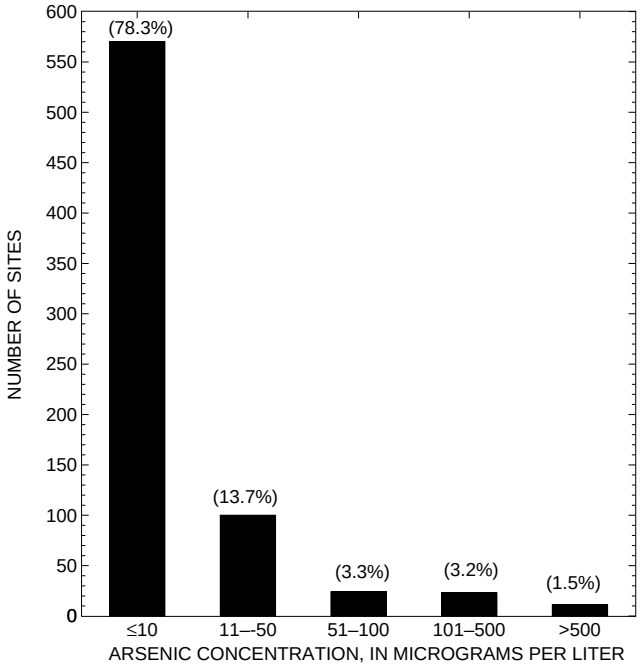

Figure 5. Arsenic concentrations for sites sampled in the Willamette Basin, Oregon. (Number in parentheses is percentage of the total number of sites.)

Depth data were available for 651 of the 728 sites. The relation of arsenic concentration to depth is shown on figure 6. Data from springs were included on this figure; springs were assigned a "well depth" of zero. (For plotting purposes, censored data [concentrations below reporting levels] were arbitrarily plotted at one-half of the reporting

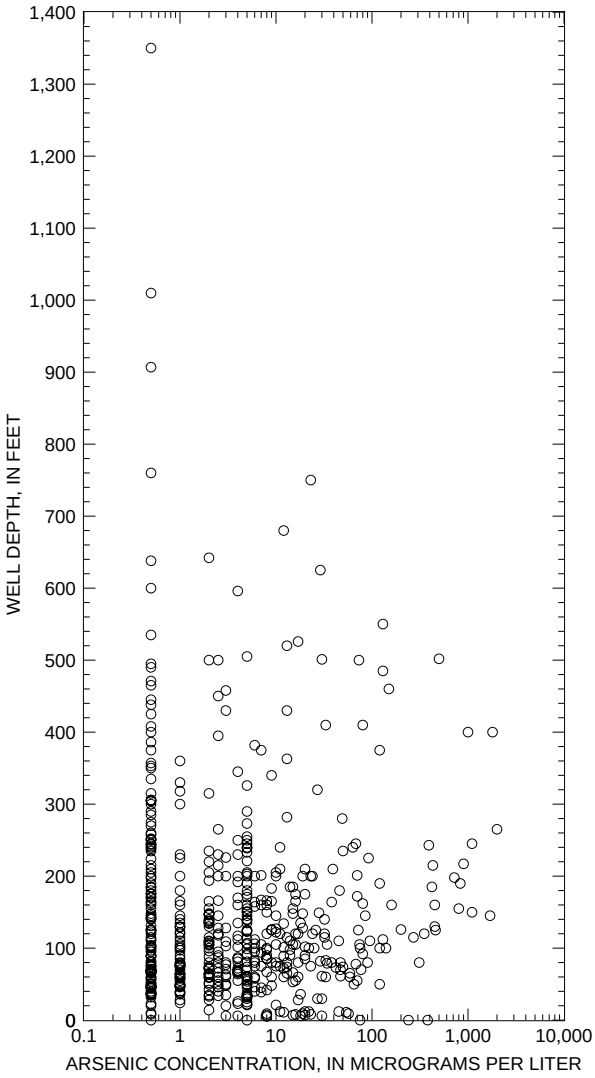

Figure 6. Relation of arsenic concentration to well depth. (Data from six springs also are included; "well depth" is set to zero for springs.)

levels. Censoring occurred at three concentration levels: 1, 5, and 10 µg/L.) No obvious relation of arsenic concentration to well depth was observed. On a regional scale, depth does not appear to be a useful parameter for predicting arsenic concentrations. However, depth may be an important parameter on a local scale.

The spatial distribution of arsenic concentrations is shown on plate 1. Patterns of arsenic occurrence are apparent. Most (53) of the 58 samples with high concentrations of arsenic came from wells and springs in bedrock areas (areas where bedrock is exposed at land surface or is covered by thin layers of alluvium) in south-central and eastern Lane County, and Linn County (pl. 1). The remain-

ing 5 (of the 58) samples came from wells near the center of the Tualatin Basin in Washington County (northwestern part of the Willamette Basin) (pl. 1). These five wells produce water from alluvial deposits. Not only were most of the 58 occurrences of high arsenic concentrations in Lane and Linn Counties, but the highest concentrations also were found there. Arsenic concentrations ranged up to 2,000 µg/L in Lane and Linn Counties, and six samples contained ≥1,000 µg/L. In contrast, the maximum concentration of arsenic in the Tualatin Basin, 77 µg/L, was substantially smaller than many of the concentrations found in Lane and Linn Counties, although still a concentration of considerable concern.

All five exceedances of the USEPA current MCL in the Tualatin Basin were from filtered samples. Many of the exceedances of the USEPA current MCL in Lane and Linn Counties were from unfiltered samples, but concentrations in filtered samples from that part of the Willamette Basin have been observed to exceed 1,000 µg/L. Because filtered samples generally contain primarily dissolved constituents, the presence of high concentrations of arsenic in filtered samples suggests that geochemical conditions can be favorable for development of high dissolved-arsenic concentrations both in the Tualatin Basin and in bedrock areas of Lane and Linn Counties.

Intermediate arsenic concentrations (>10 µg/L and ≤ 50 µg/L) were widespread in the Willamette Basin (pl. 1). As might be expected, many of the occurrences of intermediate arsenic concentrations were located in the same regions where high arsenic concentrations were found. However, intermediate arsenic concentrations were found in many other areas as well, and in a variety of geologic materials.

Occurrence of high concentrations of arsenic in bedrock areas of Lane and Linn Counties appears to be related to the areal extent of two associations of older volcanic rocks: (1) the Fisher and Eugene Formations and correlative rocks (Oligocene and upper Eocene epochs), and (2) undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt (Miocene and Oligocene epochs). (The undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt are approximately equivalent to the Little Butte Volcanic Series of Peck and others [1964].) The surficial extent of these two rock associations is shown on plate 1. At land surface, the two rock associations cover 24 percent of the Willamette Basin. All detections of high concentrations of arsenic in Lane and Linn Counties occur in or very close to places where these volcanic rocks crop out, or in areas where thin layers of alluvial materials cover the rocks. These rocks include extensive volumes of silicic (rhyolitic) volcanic rocks. Ground water high in naturally occurring arsenic commonly is associated with volcanic rocks silicic to intermediate in composition (Welch and others, 1988). Thus, the apparent relationship between high concentrations of arsenic and geologic unit is not unexpected.

Interpretation of relationships between high concentrations of arsenic in ground water and geologic units could be improved upon at a local scale by use of more detailed (local) geologic maps. For example, although high concentrations of arsenic often occur in water within the Fisher and Eugene Formations and correlative rocks, Goldblatt and others (1963) suggest that the Fisher Formation, and not the Eugene Formation, is the source of most of the arsenic in that area. Similarly, water within basalt flows in the undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt is not a likely candidate for high concentrations of arsenic because basalt typically yields water low in arsenic (Welch and others, 1988). The regional nature of the work presented in this report, with the requisite use of regional-scale rock associations, did not allow for finer-scale interpretation of the occurrence of high concentrations of arsenic relative to geologic characteristics. However, investigators involved in local-scale ground-water assessments should be able to make use of more detailed geologic mapping to help guide sampling.

Large portions of the area covered by the Fisher and Eugene Formations and correlative rocks, and the undifferentiated tuffaceous sedimentary rocks, tuffs, and basalt, are not represented by data collected and compiled for this report. Although most of the unsampled areas underlain by these rocks are not densely populated, they are not uninhabited, and the potential for impacts to human health are not insignificant. The surface exposure of these rocks alone represents 24 percent of the area of the Willamette Basin, and their full extent is greater. Additional sampling of wells completed in these arsenic-containing rocks would better define

the spatial distribution of high-arsenic water in areas not sampled during this study. Further, the presence of high arsenic concentrations in other aquifers in the Willamette Basin (pl. 1) suggests that additional sampling might reveal still more problem areas.

GEOCHEMISTRY OF ARSENIC

An understanding of factors controlling the distribution of arsenic in ground water requires a knowledge of arsenic sources and of processes controlling arsenic mobility. To that end, possible sources of arsenic in Willamette Basin ground water are discussed in this section. Processes that have been shown to control arsenic mobility in other natural systems are discussed next. Then, arsenic speciation data collected as part of this project, along with some historical speciation data, are presented. Finally, geochemical data (including the speciation data) and information from existing interpretive reports are used to construct preliminary hypotheses regarding possible geochemical controls over mobilization of arsenic in the Willamette Basin. An understanding of arsenic sources and geochemistry in the basin could help guide future monitoring efforts both in the basin and elsewhere. However, rigorous geochemical investigation of reasonable hypotheses will be required before an adequate understanding of arsenic geochemistry in the Willamette Basin can be said to exist. Thus, this discussion may serve future research.

Sources of Arsenic

Arsenic can be introduced into ground water from anthropogenic and natural sources. Anthropogenic sources may be important in some settings. Because industrial activity tends to be localized, it would be difficult to explain regional patterns of arsenic occurrence in the Willamette Basin by introduction from industrial sources. However, arsenical pesticides such as lead arsenate were historically used in large quantities in agricultural areas of the Willamette Basin (Rinehold and Jenkins, 1993). High-arsenic ground water in bedrock areas of Lane and Linn County tends to occur in nonagricultural areas, so it is unlikely that the observed high concentrations of arsenic in ground water in those areas can be attributed to historical use of arsenical pesticides. However, in contrast to land-use patterns in the bedrock areas of Lane and Linn Counties, land use in alluvial portions of the Tualatin Basin includes a variety of agricultural land uses, and high-arsenic ground water in alluvium in the Tualatin Basin does generally coincide with occurrence of agricultural areas. Closer inspection of the data, however, shows that detections of high concentrations of arsenic in Tualatin Basin ground water generally are near rivers and streams (pl. 1). Ground water near these rivers and streams likely represents ground water near the end of ground-water flowpaths. Occurrence of high concentrations of arsenic in downgradient parts of ground-water flowpaths could result from transport of arsenic from upgradient areas where arsenical pesticides historically had been applied, or from mobilization of naturally occurring arsenic during geochemical evolution as ground water moves along flowpaths. Arsenic is nearly immobile in topsoils, and arsenic in arsenical-pesticide-contaminated topsoil leaches on timescales of decades or more (Aten and others, 1980). Thus, occurrence of high concentrations of arsenic primarily in downgradient areas, and not more uniformly distributed in the Tualatin Basin, is more consistent with a natural source than an anthropogenic source. However, no rigorous ground-water flowpath analysis has been done for arsenic transport in the Tualatin Basin, and instances of leaching of arsenic from sites of historical arsenical use into ground water of the Tualatin Basin cannot be ruled out. Nonetheless, regional patterns of arsenic concentrations in ground water of the Willamette Basin as a whole probably reflect primarily natural sources.

Naturally occurring arsenic commonly is found in volcanic glass in volcanic rocks of rhyolitic to intermediate composition; adsorbed to and coprecipitated with metal oxides, especially iron oxides; adsorbed to clay-mineral surfaces; and associated with sulfide minerals and organic carbon (Welch and others, 1988). Sulfide minerals can contain arsenic either as a dominant mineral-forming element or as an impurity; sulfide minerals are found locally in the Western Cascades (U.S. Geological Survey, 1969). Metal oxides and clay minerals are ubiquitous in the Willamette Basin. Organic carbon is widespread in many parts

of the Willamette Basin, especially in alluvial deposits. Volcanic glass, commonly a major component of volcanic rocks, also is widely found in Willamette Basin aquifers, although much of the original glass in older volcanic rocks has been devitrified (Peck and others, 1964). Thus, arsenic originally associated with such volcanic glass either will have become associated with devitrification alteration products such as clays and metal oxides, or will have been released into solution and subsequently adsorbed or precipitated elsewhere or flushed from the aquifer. However, volcanic glass is still abundant in the Willamette Basin, and thus may constitute a current source of arsenic. At a minimum, the apparent relationship between rock associations containing silicic volcanic rocks and the occurrence of high concentrations of arsenic in ground water in Lane and Linn Counties described earlier in this report suggests that considerable amounts of arsenic might ultimately have come from volcanic glass. Thus, several sources of naturally occurring arsenic dispersed in aquifer materials can reasonably be postulated. However, examination of these various potential arsenic sources for arsenic availability in the Willamette Basin apparently has never been done.

Review of Geochemical Processes Controlling Arsenic Mobility

Two categories of processes largely control arsenic mobility in aquifers: (1) adsorption and desorption reactions and (2) solid-phase precipitation and dissolution reactions. Attachment of arsenic to an iron oxide surface is an example of an adsorption reaction. The reverse of this reaction, arsenic becoming detached from such a surface, is an example of desorption. Solid-phase precipitation is the formation of a solid phase from components present in aqueous solution. Precipitation of the mineral calcite, from calcium and carbonate present in ground water, is an example of solid-phase precipitation. Dissolution of volcanic glass within an aquifer is an example of solid-phase dissolution.

Arsenic adsorption and desorption reactions are influenced by changes in pH, occurrence of redox (reduction/oxidation) reactions, presence of competing anions, and solid-phase structural changes at the atomic level. Solid-phase precipitation and dissolution reactions are controlled by solution chemistry, including pH, redox state, and chemical composition.

Adsorption and Desorption Processes

Arsenic is a redox-sensitive element. This means that arsenic may gain or lose electrons in redox reactions. As a result, arsenic may be present in a variety of redox states. Arsenate and arsenite are the two forms of arsenic commonly found in ground water (Masscheleyn and others, 1991). Arsenate generally predominates under oxidizing conditions. Arsenite predominates when conditions become sufficiently reducing. Under the pH conditions of most ground water, arsenate is present as the negatively charged oxyanions $H_2AsO_4^-$ or $HAsO_4^{2-}$, whereas arsenite is present as the uncharged species $H_3AsO_3^0$ (Hem, 1985). The strength of adsorption and desorption reactions between these different arsenic species and solid-phase surfaces in aquifers varies, in part, because of these differences in charge. Differences in species charge affect the character of electrostatic interactions between species and surfaces.

Arsenate and arsenite adsorb to surfaces of a variety of aquifer materials, including iron oxides, aluminum oxides, and clay minerals. Adsorption and desorption reactions between arsenate and iron-oxide surfaces are particularly important controlling reactions because iron oxides are widespread in the hydrogeologic environment as coatings on other solids, and because arsenate adsorbs strongly to iron-oxide surfaces in acidic and near-neutral-pH water (Dzombak and Morel, 1990; Waychunas and others, 1993). However, desorption of arsenate from iron-oxide surfaces becomes favored as pH values become alkaline (Fuller and Davis, 1989; Dzombak and Morel, 1990). The pH-dependence of arsenate adsorption to iron-oxide surfaces appears to be related to the change in iron-oxide net surface charge from positive to negative as pH increases above the zero-point-of-charge (pH at which the net surface charge is equal to zero) of about 7.7 for goethite (crystalline iron oxide) (Stumm and Morgan, 1996) or 8.0 for ferrihydrite (amorphous iron oxide) (Dzombak and Morel, 1990). Where pH values are above about 8, the negative net surface charge of

iron oxide can repel negatively charged ions such as arsenate.

Iron-oxide surfaces also adsorb arsenite, and both arsenate and arsenite adsorb to aluminum oxides and clay-mineral surfaces. However, these adsorption reactions appear generally to be weaker than is the case for arsenate adsorption to iron-oxide surfaces under typical environmental pH conditions (Manning and Goldberg, 1997). Nevertheless, pH-dependent adsorption and desorption reactions other than those between arsenate and iron-oxide surfaces may be important controls over arsenic mobility in some settings. As is the case for adsorption of arsenate to iron-oxide surfaces, adsorption of arsenite to iron-oxide surfaces tends to decrease as pH increases, at least between the range from pH 6 to pH 9 (Dzombak and Morel, 1990). Unfortunately, arsenate and arsenite adsorption and desorption reactions with other common surfaces are less well characterized, and apparently more complex than is the case for adsorption and desorption reactions with iron-oxide surfaces (Manning and Goldberg, 1997).

As a result of the pH dependence of arsenic adsorption, changes in ground-water pH can promote adsorption or desorption of arsenic. Because solid-phase diagenesis (water-rock interaction) typically consumes H^+ (Stumm and Morgan, 1996), the pH of ground water tends to increase with residence time, which, in turn, increases along ground-water flowpaths. Because iron-oxide surfaces can hold large amounts of adsorbed arsenate, geochemical evolution of ground water to high (alkaline) pH can induce desorption of arsenic sufficient to result in exceedances of the USEPA current MCL in some environments (see, for example, Robertson, 1989).

Similarly, redox reactions can control aqueous arsenic concentrations by their effects on arsenic speciation, and hence, arsenic adsorption and desorption. For example, reduction of arsenate to arsenite can promote arsenic mobility because arsenite is generally less strongly adsorbed than is arsenate. Redox reactions involving either aqueous or adsorbed arsenic can affect arsenic mobility (Manning and Goldberg, 1997).

Arsenic adsorption also can be affected by the presence of competing ions. In particular, phosphate and arsenate have similar geochemical behavior, and as such, both compete for sorption sites (Hingston and others, 1971; Livesey and Huang, 1981; Manning and Goldberg, 1996). Oxyanions in addition to phosphate also may compete for sorption sites. For example, Robertson (1989) suggested that correlation of arsenate with oxyanions of molybdenum, selenium, and vanadium in ground water of the Southwestern United States may be evidence for competitive adsorption among those oxyanions.

Finally, structural changes in solid phases at the atomic level also affect arsenic adsorption and desorption. For example, conversion of ferrihydrite to goethite or to other crystalline iron-oxide phases may occur gradually over time (Dzombak and Morel, 1990). Fuller and others (1993) demonstrated that as ferrihydrite crystallizes into goethite, the density of arsenic adsorption sites decreases. This decrease in density of adsorption sites can result in desorption of adsorbed arsenic. Structural changes in other solid phases may possibly affect arsenic mobility, too. The role of such solid-phase structural changes on ground-water arsenic concentrations has, however, received little attention to date.

Precipitation and Dissolution Processes

The various solid phases (minerals, amorphous oxides, volcanic glass, organic carbon) of which aquifers are composed exist in a variety of thermodynamic states. At any given time, some aquifer solid phases will be undergoing dissolution, whereas others will be precipitating from solution. Arsenic contained within solid phases, either as a primary structural component of or an impurity in any of a variety of solid phases, is released to ground water when those solid phases dissolve. Similarly, arsenic is removed from ground water when solid phases containing arsenic precipitate from aqueous solution. As an example, because arsenic often coprecipitates with iron oxide (Waychunas and others, 1993), iron oxide may act as an arsenic source (case of dissolution) or a sink (case of precipitation) for ground water. Furthermore, solid-phase dissolution will contribute not only arsenic contained within that phase, but also any arsenic adsorbed to the solid-phase surface. The process of release of adsorbed arsenic as a result of solid-phase dissolution is distinct from the process of desorption from stable solid phases.

The interplay of redox reactions and solid-phase precipitation and dissolution may be particularly important with regard to aqueous arsenic and solid-phase iron oxides and sulfide minerals. High concentrations of arsenic often are associated with iron oxides and sulfide minerals (Thornton, 1996). Iron oxides frequently dissolve under reducing conditions, but often precipitate under oxidizing conditions. Sulfide minerals generally are unstable under oxidizing conditions, but may precipitate under reducing conditions. Thus, as a result of the redox-sensitive nature of iron oxides and sulfide minerals, transfer of large amounts of arsenic between these solid phases and neighboring water may result from redox-facilitated precipitation and dissolution reactions.

Arsenic Speciation in the Willamette Basin

Three samples from alluvial wells in the Tualatin Basin and two from bedrock wells in Lane County were analyzed for four common species of arsenic. Concentrations of the two organic species of arsenic analyzed (monosodium methylarsonate, or CH_3AsO_3HNa, and sodium dimethylarsinate, or $(CH_3)_2AsO_2Na$) were below MDLs, so only the data for the two inorganic species are tabulated. These speciation data are given in table 4.

Two additional analyses for arsenic species in ground water from the Willamette Basin were available in the literature. Welch and others (1988) reported arsenite and arsenate concentrations for water from two wells in Lane County. Arsenite represented 7 percent and 62 percent of the total arsenic in these samples (total arsenic concentrations being 25 and 45 µg/L, respectively).

The most striking feature of the data from the two studies is the predominance of arsenite. The predominance of arsenite has both geochemical and toxicological implications. From a geochemical standpoint, the speciation data are of interest because mobility of arsenite differs from that of arsenate (see section “Review of Geochemical Processes Controlling Arsenic Mobility”). From a public-health perspective, the speciation data are interesting because arsenite is more toxic than arsenate in at least some of its effects. In human acute toxicity studies, arsenite has been shown to be more potent than arsenate (U.S. Environmental Protection Agency, 1988). With regard to human chromosome breakage, arsenite is about an order of magnitude more potent than arsenate (U.S. Environmental Protection Agency, 1988). Morrison and others (1989) report that arsenite is 50 times as toxic as arsenate, but do not report the organisms studied. Also, arsenite is more difficult to remove from drinking-water supplies than is arsenate (Gupta and Chen, 1978; Schneiter and Middlebrooks, 1983). However, it would be premature to make generalizations regarding arsenic toxicity in the Willamette Basin based upon such limited speciation data (seven samples). Complicating the matter, in the benchmarks against which drinking water arsenic concentration data commonly are compared—the USEPA current MCL and the WHO provisional guideline—no differen- tiation is made between arsenite and arsenate. But if the apparent predominance of arsenite in Willamette Basin ground water is confirmed by additional speciation work, public health officials and water managers may need to evaluate the scope of the arsenic problem with regard not only to arsenic concentrations, but also to arsenic speciation.

Table 4. Speciation of arsenic

[Total arsenic concentration is from a separate analysis of a separate sample, and differs from the total of arsenite-plus-arsenate because of sampling and (or) analytical variability. Recovery, total of arsenite-plus-arsenate divided by total arsenic; µg/L, micrograms per liter]

Well location	Date	Arsenite (percent of total of arsenite-plus-arsenate)	Arsenate (percent of total of arsenite-plus-arsenate)	Arsenite (µg/L)	Arsenate (µg/L)	Total of arsenite-plus-arsenate (µg/L)	Total arsenic concentration (µg/L)	Recovery (percent)
01N/03W-04CCC	08/19/97	76	24	61.1	18.9	80.0	97	82
01S/03W-10BCA1	08/19/97	96	4	58.8	2.3	61.1	56	110
02S/02W-11CCD1	08/19/97	94	6	15.3	.9	16.2	19	85
18S/04W-14BBA	08/20/97	>99	<1	1,200	6.1	1,210	1,100	110
19S/03W-31E1	08/20/97	68	32	61.5	29.4	90.9	130	70

Geochemistry of Arsenic in the Willamette Basin

Few routine chemical analyses (of major ions and field parameters) are available for high-arsenic ground water from bedrock areas of Lane and Linn Counties. Goldblatt and others (1963) noted that high-arsenic ground water tended to have high pH (>8.0) and high orthophosphate concentrations, although only two routine chemical analyses for high-arsenic ground water were published. Reliable measures of redox conditions were not collected. However, the observation was made during site visits that water from many of the wells in bedrock areas of Lane and Linn Counties that yielded high-arsenic ground water during project sampling also had sulfide odors. The presence of sulfide in water indicates chemically reducing conditions. The observation of sulfide, along with the detection of arsenite (the more reduced of the two major arsenic species) in some ground-water samples, indicates the presence of reducing conditions in some ground water in these areas.

Together, these data suggest that for ground water in bedrock areas of Lane and Linn Counties, one or more of the following controlling factors likely are important in adsorption and desorption reactions that in turn often control arsenic mobility: (1) high pH, (2) presence of competing anions, and (3) occurrence of reducing conditions. The sparse available data do not allow even for speculation about adsorption and desorption reactions related to solid-phase structural changes at the atomic level in ground water of bedrock areas of Lane and Linn Counties. Similarly, evidence is lacking to even begin to develop hypotheses about solid-phase precipitation and dissolution reactions.

Previous investigations of the quality of Tualatin Basin ground water provide some preliminary insight into arsenic geochemistry there. Rounds and others (1994) reported that high phosphorus concentrations (up to 2.9 mg/L [milligrams per liter]) are common in Tualatin Basin ground water. In an analysis of 47 filtered ground-water samples from the Tualatin Basin, Hinkle (1997) reported that the median arsenic concentration in low-dissolved-oxygen samples (dissolved oxygen concentrations < 1.0 mg/L) was greater than the median arsenic concentration in well-oxygenated samples. The difference was statistically significant. Of the 47 samples, the 4 that exceeded the USEPA current MCL not only had low dissolved-oxygen concentrations, but also had high concentrations of orthophosphate (0.36 to 2.0 mg/L) and iron (160 to 1,900 µg/L). However, pH was not unusually high; pH of three of the four high-arsenic samples ranged from 7.5 to 7.6, and was 8.1 for the fourth sample.

These data suggest that for alluvial ground water in the Tualatin Basin, presence of competing anions and occurrence of reducing conditions may be important controlling factors in arsenic adsorption and desorption reactions. These two factors might be more important than pH controls over arsenic adsorption and desorption. Reducing conditions and high concentrations of dissolved iron also suggest that dissolution of iron oxides, with subsequent release of adsorbed or coprecipitated arsenic, may play a role in arsenic mobility in the Tualatin Basin.

Hypotheses about factors affecting arsenic adsorption and desorption reactions should account for arsenic speciation. Limited geochemical data suggest that desorption of arsenic from solid phases may be an important process in ground water both in bedrock areas of Lane and Linn Counties and in alluvium in the Tualatin Basin. Desorption of arsenate from iron oxides commonly results from high pH or the presence of competing ions. Such processes, of course, require the presence of arsenate on solid-phase surfaces. Because redox reactions often are slow and frequently far from equilibrium, it would not be unexpected to find arsenate adsorbed to solid-phase surfaces in chemically reducing environments. It might appear, though, that the predominance of arsenite relative to arsenate in aqueous speciation samples would be inconsistent with a hypothesis of desorption of arsenate from iron-oxide surfaces. However, it may be that arsenate is desorbed from aquifer surfaces and subsequently reduced to arsenite.

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APPENDIX

APPENDIX

Table 1. Wells discussed in report text, tables, and figures, listed by well location name from original source, and cross-referenced by recalculated well location and by U.S. Geological Survey site identification number and Oregon Water Resources Department well log identification number
["--", identical to "Well location (original source)"; N/A, none or not determined].

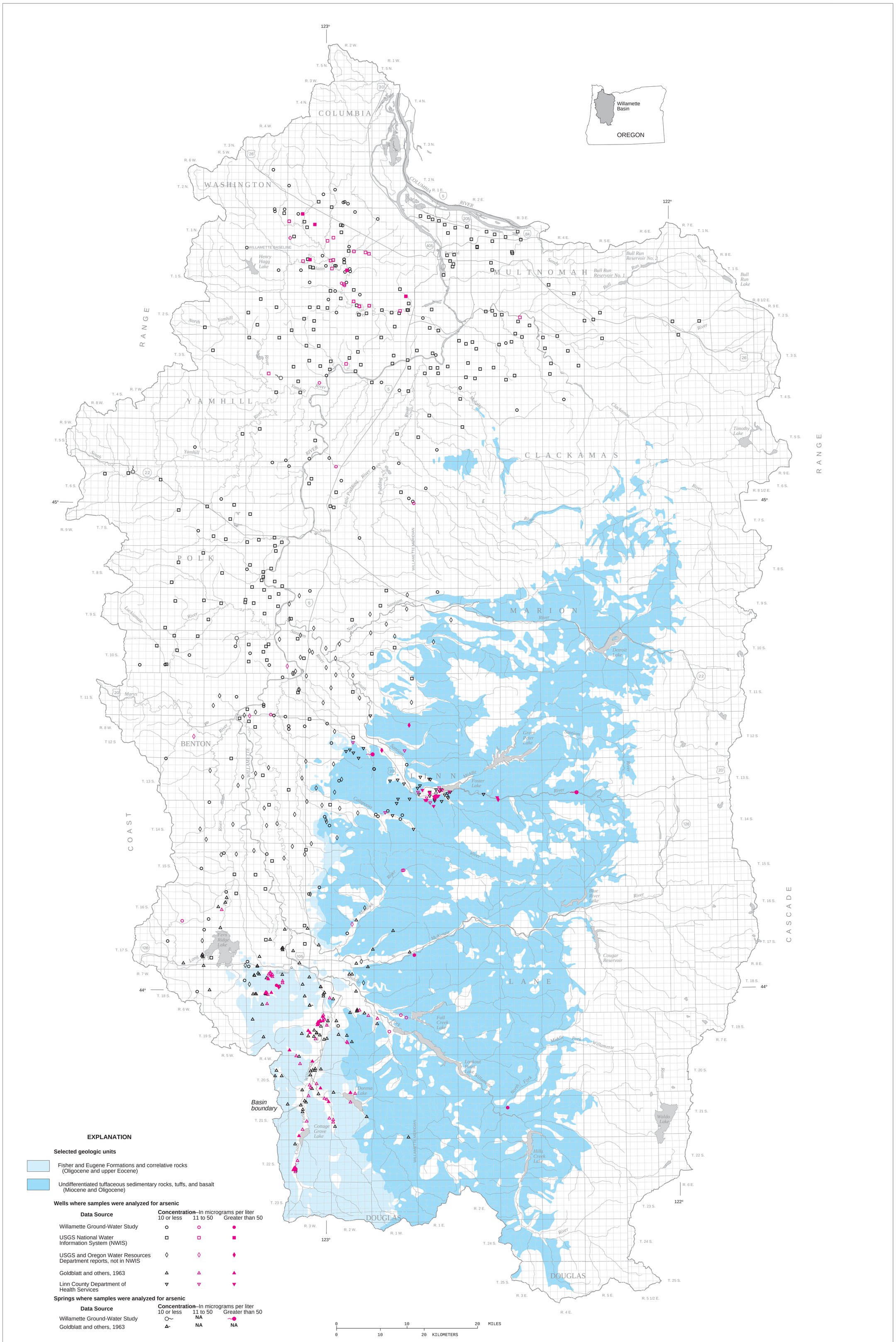
Well location (original source)	Well location (recalculated)	U.S. Geological Survey site identification number	Oregon Water Resources Department well log identification number
01N/03W-04CCC	--	453540123041101	WASH 5967
01N/03W-07CCD1	--	453445123063201	WASH 6037
01N/03W-15ADB1	--	453422123020201	N/A
01S/02W-29DBD	--	452707122572201	WASH 10406
01S/02W-33BBA	--	452651122565001	WASH 10475
01S/03W-10BCA1	--	453002123025301	WASH 143
02S/02W-11CCD1	--	452416122541601	WASH 12572
12S/01W-29N1	12S/01W-29CCA	442934122502801	LINN 9588
13S/01E-33	13S/01E-33DB1	442332122412701	LINN 12832
13S/01E-33AC	--	442348122412301	LINN 12776
13S/01E-35	13S/01E-35BD1	442347122391001	LINN 12914
14S/01E-05	13S/01E-32CD1	442323122424801	LINN 10997
15S/01W-23CCA	--	441447122464501	LANE 50736
15S/01W-23CCC2	--	441446122465701	LANE 5873
17S/01W-24DCA	--	440420122445701	LANE 2085
18S/04W-10D	18S/04W-10BB1	440125123095901	N/A
18S/04W-14ACA	--	440029123080301	LANE 17048
18S/04W-14ACB	--	440024123080901	LANE 17052
18S/04W-14BBA	--	440036123083201	LANE 16780
18S/04W-22B	18S/04W-22BA1	435942123092501	N/A
19S/01W-03ADB	--	435656122471801	LANE 19429
19S/03W-11E2	19S/03W-11BC3	435606123012501	N/A
19S/03W-31E1	19S/03W-31BB1	435237123061801	N/A
21S/03E-08CBD2	--	434528122290901	LANE 23527
22S/03W-17N	22S/03W-17CC1	433859123045601	N/A

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with
OREGON WATER RESOURCES DEPARTMENT

WATER-RESOURCES INVESTIGATIONS REPORT 98-4205
Arsenic concentrations in ground water, and selected geologic units—PLATE 1

Hinkle, S.R. and Polette, D.J.
Arsenic in Ground Water of the Willamette Basin, Oregon



Base modified from U.S. Geological Survey Digital base from
U.S. Geological Survey Digital Line Graphs published at 1:100,000, 1987;
U.S. Bureau of the Census, TIGER/Line(R), published at 1:100,000, 1990;
U.S. Geological Survey Digital Line Graphs published at 1:100,000, 1988
and modified by the State of Oregon. 1994;
U.S. Geological Survey quadrangle maps published at 1:24,000
as digitized by Oregon Department of Transportation;
Universal Transverse Mercator projection, Zone 10
1927 North American Datum

Geology from Walker and MacLeod, U.S. Geological Survey Digital Line G
published at 1:500,000, 1991 and modified by the State of Oregon, 199

DISTRIBUTION OF ARSENIC CONCENTRATIONS IN GROUND WATER, AND SELECTED GEOLOGIC UNITS OF THE WILLAMETTE BASIN, OREGON

By
Danial J. Polette and Stephen R. Hinkle