Soil, Plant and Water Analytical Laboratories for Montana Agriculture

by Jeffrey Jacobsen and Scott Lorbeer*

*Interim department head and Extension soil scientist (Jacobsen) and research associate (Lorbeer), Montana State University, Department of Plant, Soil and Environmental Sciences

Contents

List of Tables

Preface

Because Montana has no state-supported laboratories that provide in-depth analysis of soil, water and plant nutrients, Montana producers must look to private laboratories in Montana and state-supported and private labs in other states for routine fertility analysis and problem diagnosis for soil, plant and water samples. Questions sometimes arise concerning consistency between labs and the validity of the results. While producers report greater confidence in private labs than when this publication's predecessor was first written in 1986, the intent of this bulletin is to continue to educate the public by stimulating questions and discussions—ultimately providing sound analytical services and guidelines for interested Montana producers. Guidelines and recommendations have been included to assist Montana farmers and ranchers who have implemented routine soil, plant and water analytical programs with their nutrient management and cropping decisions.

As consumers, you are purchasing a product and can expect some technical assistance when you use a lab. Follow the lab's protocol when collecting representative soil, plant and water samples for submission. Use a reputable laboratory, expect consistency and most importantly, ask questions.

This guide is not intended to be all inclusive. Additional reference sources such as the Extension Service, Experiment Station, industry, other consumers and written materials can be used in the decision-making process.

Introduction and Objectives

Sixteen elements have been identified as essential nutrients for plant growth. Carbon (C), hydrogen (H) and oxygen (O) are used in large amounts and are derived from air and water. Nitrogen (N), phosphorus (P) and potassium (K), the primary or macronutrients, and calcium (Ca), magnesium (Mg) and sulfur (S), the secondary nutrients, are required in relatively large amounts from the soil. Elements required in relatively small amounts (micronutrients) from the soil include zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B), molybdenum (Mo) and chloride (Cl). Leguminous crops are capable of utilizing atmospheric N. Precipitation and irrigation water can also supply some essential plant nutrients. Chemical analysis of soil, plant and water samples indicates nutrient availability and the need for fertilizer additions to correct deficiencies and aid in problem diagnosis.

Plant nutrient requirements in relatively new cropping systems and virgin soils were traditionally met by nutrients already present in soil. As crop production continued and as yields increased, the inherent nutrient-supplying capacity of soils began to decline. Realizing this, producers and scientists continuously attempted to determine the dynamic soil nutrient status, compare it with crop nutrient demands and supply the differences with nutrient applications. The net result is high crop quality and yield, while maintaining environmental quality. These are some of the reasons for the evolution and widespread acceptance of analytical programs and laboratories.

A soil analysis is a chemical means of estimating the nutrient-supplying power of the soil. Soil analysis objectives include:

- estimate of available soil nutrient quantities
- identification of nutrient deficiencies, toxicities and other problems
- establishment of guidelines for nutrient applications
- documented, meaningful results for economic evaluation of nutrient recommendations

Accurate soil, plant and water analytical records are needed to fully evaluate nutrient applications and manage the soil's productivity over time.

Private and commercial laboratories commonly provide soil, plant and water analytical services. Montana farmers and ranchers currently send samples to laboratories within Montana and out of state. To provide current, accurate information on the availability of services provided by these laboratories, all the labs were surveyed. Their responses were used to compile this bulletin and reflect the current services offered by analytical laboratories. Efforts to ensure the accuracy and completeness of each survey were made, especially if information appeared ambiguous. The authors of this bulletin have made no attempt to interpret, modify or standardize the responses, and make no claims for the data. The mention or exclusion of specific laboratories constitutes neither endorsement nor disapproval of a specific laboratory.

The objective of this publication is to provide Montana farmers and ranchers with a variety of information on the soil, plant and water analytical services provided by laboratories. Our goal is to show producers the variety of analytical tests, methodologies and reporting units and provide a basis for data interpretation and nutrient recommendations. Nutrient recommendations from laboratories may or may not be useful to Montana producers. Records should be kept to determine if nutrient recommendations are worthwhile and profitable with adjustments made as needed. Actual analytical results also may or may not be transferable to current Montana nutrient guides and recommendations, but they offer an additional option for nutrient recommendations.

Survey Overview

A soil analysis is a chemical, physical or microbiological technique that estimates the availability of essential nutrients in the soil for plant growth. Plant and water analyses determine actual nutrient concentrations. For soil, plant and water analyses to be meaningful, samples must be representative of the field or area, prepared properly for sample submission, and accurately extracted and analyzed. Extraction and analytical procedures for soil analysis should reflect nutrient availability, with results correlated to known crop responses. Field calibration studies conducted over many years and locations are then used as the basis for making nutrient recommendations. Calibration studies are an ongoing process to keep nutrient recommendations current with new technologies and varieties. In addition to soil analysis results, nutrient recommendations are based on the crop to be grown, planting pattern and rate, yield potential, and method and timing of nutrient application.

Survey results indicate a wide range in analytical capabilities, techniques, reporting units, recommendation philosophies and prices from laboratories commonly used by Montana farmers. This wide range in procedures accounts for some of the differences in results and recommendations from duplicate soil samples sent to several

Table 1. Summary of soil analysis services offered to Montana producers by laboratory.

Element/ Method or Compound	Agvise Labs	Astro-Chem Lab	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Laboratory, NDSU	Soiltest Farm Consultants	Stuken-holtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Nitrogen (N)														
Total N	x		x	x	x	x	x	x	x		x	x	x	
Ammonium-N (NH_4-N)	x		x	x	x	x	x	x	x		x	x	x	x
Nitrate-N (NO_3-N)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Phosphorus (P)														
Bray	x		x	x	x	x	x	x			x	x	x	
Olsen	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Morgan											x		x	
Water soluble P												x	x	
Potassium (K)														
Ammonium acetate	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Water				x		x								
Sodium acetate											x		x	
Sodium bicarbonate											x		x	
Calcium (Ca)														
Ammonium acetate	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Water				x		x								
Sodium acetate											x			
Potassium chloride											x			
Magnesium (Mg)														
Ammonium acetate	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Water				x		x								
Sodium acetate											x			
Potassium chloride											x			
Sodium (Na)														
Ammonium acetate	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 1, continued

Element/ Method or Compound	Agvise Labs	Astro-Chem Lab	B & C Ag Con-sultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Laboratory, NDSU	Soiltest Farm Consultants	Stuken-holtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Sulfur (S)														
Total S				x		x	x	x	x		x	x		
Sulfate-S (SO_4-S)	x	x	x	x	x	x		x	x	x	x	x	x	x
Organic-S				x		x								
Zinc (Zn)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manganese (Mn)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Copper (Cu)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Iron (Fe)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Boron (B)	x	x	x	x	x	x	x	x	x		x	x	x	x
Molybdenum (Mo)				x	x	x	x		x					
Chloride (Cl)	x		x	x	x	x	x	x			x		x	x
GENERAL														
Organic matter (OM)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total Carbon				x		x		x					x	
Organic C	x			x	x	x	x	x	x	x	x	x	x	x
Walkley-Black	x		x	x		x	x		x		x	x	x	x
Ignition		x		x	x		x	x	x	x				
pH	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Electrical conductivity (EC)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cation exchange capacity (CEC)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Available water-holding capacity	x		x		x	x	x	x			x	x	x	
Pressure plate	x		x		x	x	x	x					x	
Texture-mechanical analysis	x		x	x	x	x	x	x		x	x	x	x	
Texture estimate			x	x				x		x				x

laboratories by Montana producers. For example, some laboratories air-dry samples, while others oven-dry samples in a temperature range of 90–130° F. The water content and physical effects of drying on soil particles affect the level of extractable nutrients. Questions have arisen as to which results and recommendations are correct and why there are differences in results, even when the same procedure is used by two different labs. Several factors account for the differences: sample variability, different sample preparation, modification of standard procedures, philosophical differences in nutrient recommendations, reporting units, analytical errors and chance.

This bulletin provides a summary of the information and services offered by each laboratory. It lists routine analyses grouped in a package, general methods employed by all laboratories, and reporting units used for each test. We also include a list of the names, addresses and phone numbers of the appropriate contacts at each laboratory (see page 21).

Soil Analysis Services

Soil analysis

Many options are available for soil sample analysis (Table 1, pages 4 and 5). The variety and number of analyses can be confusing, frustrating and, if misinterpreted, may lead to an erroneous recommendation and misapplication of nutrients. Suggested analyses are provided to identify those tests necessary for routine programs, assuming no problem areas are evident. Individual methods for examining several nutrients have been identified which are suitable for Montana conditions, although other methods may also be acceptable.

Montana has a semiarid climate. Consequently most soils are alkaline. The most common methodology and elemental analysis preferred for routine soil analysis programs in Montana include pH, nitrate-nitrogen, Olsen phosphorus, ammonium acetate extractable potassium, Walkley-Black organic matter and electrical conductivity. Additional fertility analyses that may be necessary in some areas include sulfate-sulfur, ammonium acetate extractable calcium and magnesium and, in isolated areas, DTPA (diethylenetriaminepentaacetic acid) extractable zinc, manganese, copper, iron, hot water extractable boron and chloride.

Increased crop growth from application of sulfur has been observed in locations west of the Continental Divide, irrigated sites, and on canola and forages in other areas. Few documented examples of increased crop growth due to application of micronutrients have been observed, although some positive responses were reported on soils with high pH—generally on hilltops or locations with limited topsoil due to erosion, natural conditions or land leveling operations. Foliar applications of micronutrients will correct deficiencies in most instances. Boron applications may benefit alfalfa and sugarbeet production, although nutritional requirements are usually met through irrigation water. Molybdenum analysis historically has not been needed, and the element is not likely to become a problem in Montana. Toxicity problems may exist in some isolated areas due to the accumulation of boron, chloride, sodium or salts. Sensitive plants will not tolerate soil levels greater than 0.75 ppm B, 70 ppm Cl and in the saturation extract, exchangeable sodium percentage (ESP) of 15 and electrical conductivity of 4 milli mhos per centimeter (mmhos/cm). Although included in some analysis packages, secondary and micronutrient tests generally are not necessary under most production conditions for Montana soils. They increase analysis costs and in some cases, add confusion. Nutrient recommendations, if followed, would result in increased application costs.

Nutrient guides for small grains, forage crops and other field crops are available to help Montana producers make decisions

Table 2. Reasonable soil analysis ranges and critical levels from essential nutrient analysis and chemical characteristics in Montana soils.

Element or soil characteristic	Normal soil analysis range	Critical soil analysis level*
Nitrate-N	0 - 50 lbs/a	
Phosphorus (Olsen)	0 - 40 ppm	18.0 ppm
Potassium	0 - 500 ppm	250.0 ppm
Calcium	0 - 1000 ppm	400.0 ppm
Magnesium	0 - 100 ppm	40.0 ppm
Sulfate-S	0 - 50 lbs/a	10.0 ppm
Zinc	0 - 15 ppm	0.5 ppm
Manganese	0 - 10 ppm	1.0 ppm
Copper	0 - 1 ppm	0.5 ppm
Iron	0 - 10 ppm	2.5 ppm
Boron	0 - 10 ppm	1.0 ppm
Molybdenum	0 - 2 ppm	0.1 ppm
Chloride	0 - 60 lbs/a	
pH	6 - 8.4	
Organic matter	0 - 4 %	
Electrical conductivity	0 - 4 mmhos/cm	
Cation exchange capacity	0 - 25 meq/100 g	
Exchangeable sodium percentage	0 - 15	

* *The level of a nutrient below which crop yield, quality or performance is unsatisfactory.*

based on actual analytical results from most labs. Nitrogen requirements are determined from the specific crop and yield potential with actual recommendations influenced by the nitrate-nitrogen concentration, time of sampling, depth of sampling, soil organic matter level, previous crop, crop residue and economics of fertilization. Phosphorus and potassium nutrient requirements are based on the crop to be grown and calibrated research results from field and greenhouse studies.

Reasonable soil analytical ranges for essential nutrients and pertinent soil characteristics from most agricultural soils in Montana are provided in Table 2. Soil analysis results outside this range may indicate high residual nutrient levels, decreased nutrient requirements from historically high fertilization levels, toxicity problems or laboratory error. Consult a soil scientist if soil test values are drastically different from average values.

Soil analysis units

Not only are many choices available in routine soil analysis, but a variety of units (the quantity measurement attached to a numeral, e.g. inch, liter, ton, acre) are used for the same procedure by different laboratories (Table 3, pages 8 and 9). Some of the differences in terms are real, while others are simply the same units expressed in different forms. For example, ppm stands for parts per million and is equivalent to mg/l (milligrams per liter) or µg/g (micrograms per gram). Some conversions may be straightforward, such as the conversion from ppm of NO_3-N to lbs/a (pounds/acre), which requires ppm to be multiplied by 2 for each 6-inch depth increment. Other conversions require some

Alphabet soup: Soil analysis units

ppm= parts per million

mg/l = milligrams per liter

µg/g = micrograms per gram

lbs/a = pounds per acre

mmhos/cm = millimhos per centimeter

µmhos/cm = micromhos per centimeter

meq/100 g = milliequivalents per 100 grams

meq/l = milliequivalents per liter

cmol(+)/kg = centimoles of positive charge per kilogram

mmol(-)/l = millimoles of negative charge per liter

dS/m = decisiemens per meter

mS/cm = millisiemens per centimeter

Table 3. Summary of soil analysis units reported to Montana producers by laboratory.

Element/ Method or Compound	Agvise Labs	Astro-Chem Lab	B & C Ag Con-sultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Lab, NDSU	Soiltest Farm Consultants	Stuken-holtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Nitrogen (N)														
Total N	%		%	µg/g	%	ppm	ppm	ppm	ppm, lbs/a		µg/g, %	%	%	
Ammonium-N (NH_4-N)	%		ppm	µg/g	ppm	ppm	ppm	ppm	ppm, lbs/a		µg/g, lbs/a	ppm	µg/g	
Nitrate-N (NO_3-N)	lbs/a	ppm, lbs/a	ppm, lbs/a	µg/g, lbs/a	ppm	ppm	ppm, lbs/a	ppm, lbs/a	ppm,lbs/a	lbs/a	µg/g, lbs/a	ppm, lbs/a	µg/g	ppm, lbs/a
Phosphorus (P)	ppm	lbs/a	ppm	µg/g	ppm	ppm	ppm	ppm	ppm, lbs/a	ppm	µg/g	ppm	µg/g	ppm
Potassium (K)	ppm	lbs/a	ppm	µg/g, meq/l	ppm	ppm, meq/l	ppm	ppm	ppm, lbs/a	ppm	µg/g	ppm	µg/g	ppm
Calcium (Ca)	ppm	ppm	meq/ 100g	µg/g, meq/l	ppm	ppm, meq/l	ppm	ppm	ppm, meq/100g	ppm	meq/100g	meq/100g	cmol(+)/kg	ppm
Magnesium (Mg)	ppm	ppm	meq/ 100g	µg/g, meq/l	ppm	ppm, meq/l	ppm	ppm	ppm, meq/100g	ppm	meq/100g	meq/100g	cmol(+)/kg	ppm
Sodium (Na)	ppm	ppm	meq/ 100g	µg/g, meq/l	ppm	ppm, meq/l	ppm	ppm	ppm, meq/100g	ppm	meq/100g	meq/100g	cmol(+)/kg	meq/ 100g
Sulfur (S)														
Total S				%		%	ppm							
Sulfate-S (SO_4-S)	lbs/a	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	lbs/a	µg/g	ppm	µg/g	ppm
Organic-S				%		ppm								
Zinc (Zn)	ppm	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Manganese (Mn)	ppm	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Copper (Cu)	ppm	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Iron (Fe)	ppm	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Boron (B)	ppm	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm		µg/g	ppm	µg/g	ppm
Molybdenum (Mo)				µg/g	ppm	ppm	ppm		ppm					

Table 3. continued

Element/ Method or Compound	Agvise Labs	Astro-Chem Lab	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Lab, NDSU	Soiltest Farm Consultants	Stukenholtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Chloride (Cl)	lbs/a		ppm, lbs/a	µg/g	ppm	ppm	ppm	lbs/a			µg/g		mmol(-)/l	ppm
General														
Organic matter (OM)	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Electrical conductivity (EC)	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm, dS/m	mmhos/cm
Cation exchange capacity (CEC)	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	% base saturation, meq/100g, ppm (soil)		meq/100g	meq/100g	cmol(+)/kg	meq/100g
Available water-holding capacity	% water by weight		inches/foot		% water by weight		%water by weight	%water by weight			inches/foot	inches/foot	% water by weight	
Texture	%		%	%	%	%	%	%		%	%	% and soil textural classification	%	soil textural classification

Table 4. Conversion factors for units reported by soil and water analytical laboratories.

Multiply	By[1]	To convert to[2]
ppm NO_3-N[3] in soil	2	lbs/a in soil
lbs/a P, K, Ca, Mg, Na, SO_4-S, Zn, Mn, Cu, Fe, B, Mo, Cl in soil	0.5	ppm in soil
meq/100 g K in soil	391	ppm in soil
meq/100 g Ca in soil	200	ppm in soil
meq/100 g Mg In soil	122	ppm in soil
meq/100 g N in soil	229	ppm in soil
meq/l K in solution	39	ppm in solution
meq/l Ca in solution	20	ppm in solution
meq/l Mg in solution	12	ppm in solution
meq/l Na in solution	23	ppm in solution

Multiply	By[1]	To convert to[2]
Other conversions		
cmol(+)/kg	1	meq/100g
µg/l	0.001	mg/l
mg/l	0.001	mg/ml
mg/l	1	ppm solution
µg/l	1000	ppm solution
ppm	0.0001	%
µg/g	1	ppm
mS/cm or dS/m	1	mmhos/cm
NO_3 (weight per volume of water)	0.2259	NO_3-N (weight per volume of water)

[1] *Divide by the "by" factor to convert the units reported in the "to convert to" columns to those reported in the "multiply" column.*

[2] *Assume 6-inch soil depth.*

[3] *For each 6-inch increment of soil depth.*

technical background. These conversion factors are provided in Table 4 (on page 9) to assist in converting units reported by surveyed laboratories to common units. Once conversions are made, nutrient recommendations should be made based on calibrated research studies conducted throughout Montana. The results received in analytical lab reports estimate true soil concentration of a particular nutrient (such as NO_3-N) or an "index" of plant available nutrients (such as P and K). Soil analysis for P and K extract only a portion of the total mineral reservoir, as only a portion of the mineral reservoir is available to crops. Different extraction procedures remove different amounts of the mineral reservoir which is then correlated to historical crop responses. For this reason, it is not helpful or appropriate to convert parts per million to pounds per acre for indices of nutrient availability.

Prices vary from these following quotes as basic packages are often discounted due to number and frequency of submitted samples. Most commercial labs offer volume discounts and sales programs, which may result in lower costs if samples are processed through a fertilizer dealer. A package that meets your particular needs can often be negotiated at a cheaper price than the sum of individual test costs. Many labs will put together a custom package if your needs vary from the packages listed here.

Basic Soil Analysis Packages

Laboratory	Cost
Agvise Laboratories Nitrate, phosphorus, potassium, sulfur, chloride, pH, salts	$16.50
Astro-Chem Lab, Inc. Nitrate-nitrogen, phosphorus, potassium, pH	$15
B & C Ag Consultants Nitrate-nitrogen, phosphorus, potassium, sulfur, sodium, organic matter, estimated organic nitrogen release, pH, salts, texture, lime	$20
Energy Laboratories, Inc. Nitrate-nitrogen, phosphorus, potassium, zinc (irrigated soils), sulfate (non-irrigated soils), nitrate on second (lower) depth	$28.50
Harris Laboratories, Inc. Nitrate-nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, manganese, copper, iron, boron, sodium, organic matter, pH, buffer pH (if pH<6.4), excess carbonate (if pH >6.4), salts, CEC, percent base saturation	$16
Maxim Technologies, Inc. Nitrate-nitrogen, phosphorus, potassium, organic matter, pH, electrical conductivity	$60
Midwest Laboratories, Inc. Nitrate-nitrogen, phosphorus, potassium, organic matter, estimated nitrogen release, magnesium, calcium, soil pH, buffer index, CEC, percent base saturation	$10.60
MVTL Laboratories, Inc. Nitrate-nitrogen, phosphorus, potassium, chloride, pH, buffer index, salts	$13.50
Sathe Analytical Laboratory, Inc. Nitrate-nitrogen, phosphorus, potassium, pH	$15
Soil Testing Laboratory, North Dakota State University Nitrate-nitrogen, phosphorus, potassium	$10.50
Soiltest Farm Consultants, Inc. Nitrate-nitrogen, phosphorus, potassium, sulfate-sulfur, boron, zinc; pH and salts can be substituted for boron and zinc at the same price	$22
Stukenholtz Laboratory, Inc. Nitrate-nitrogen, phosphorus, potassium, pH, salts, organic matter	$20
University of Idaho, Analytical Sciences Laboratory Nitrate, ammonium, phosphorus, potassium, pH, organic matter	$30
Western Testing Laboratory, Inc. Nitrate-nitrogen, phosphorus, potassium, sulfate-sulfur, copper, iron, manganese, sodium, zinc, pH, organic matter, salts, texture, lime	$25

Fertilizer recommendation strategy

Agvise Laboratories

Recommendations are based on university guidelines from Minnesota, North Dakota and South Dakota. N recommendations incorporate yield goal, crop, residual N down to 2 feet or 4 feet, and previous crop contributions. P recommendations can be straight university recommendations, or a banding amount for P and K, or a fertility building rate for P.

Astro-Chem Lab, Inc.

A university developed model that includes yield goal, crop and other parameters determines recommendation.

B&C Ag Consultants

A budget-inventory system is used, based on the difference between required N for yield goal and residual nitrate-nitrogen (NO_3-N) to two or four feet and estimated organic nitrogen release. Adjustments are made for previous crop and sampling date. Yield goals for dryland crops are derived from water use models. A budget-inventory system is used for P. P fixation rates are measured for problem soils. K guidelines follow crop yield goal and soil analysis.

Energy Laboratories, Inc.

N recommendations are based on NO_3-N concentration and organic matter release. P and K recommendations are crop-specific and depend on yield goal and soil analysis.

Harris Laboratories, Inc.

A budget approach considers the N requirement of the planned crop, previous crop, N mineralized from organic matter, residual NO_3-N, manure, yield goal and a depth efficiency factor for N recommendations. Recommended P rates are given for maintenance and build-up programs, based on soil type, soil analysis and crop removal. Maintenance K recommendations are based on soil factors and crop removal, while build-up K recommendations use these along with crop demand and a CEC factor.

Maxim Technologies, Inc.

No fertilizer guidelines provided.

Midwest Laboratories, Inc.

Organic matter, estimated N release, soil type and nitrate- and ammonium-N analysis are used to determine the total N requirement based on the crop and yield goal. P recommendations are based on soil P analysis. Fertilizer recommendations are based on a build-up program with further guides presented based on crop needs and yield potential. K needs are established based on the CEC, elemental ratios, degree of base saturation and yield goal in a build-up program.

MVTL Laboratories, Inc.

Geographic location, crop, previous crop, yield goal, organic matter, soil texture and residual NO_3-N are considered for N fertilizer recommendations. P and K guidelines consider the crop and soil analysis level for a standard, maintenance or build-up fertilizer program.

Sathe Analytical Laboratory, Inc.

Fertilizer recommendations are based on planned crop, yield goal, sample depth and previous crop.

Soil Testing Laboratory, North Dakota State University

Recommendations are for broadcast applications based on university guidelines and incorporate crop, soil analysis and yield goal.

Soiltest Farm Consultants, Inc.

Soil analysis results, crop yield goals, and zone influence fertilizer recommendation. Montana Extension Service fertilizer guidelines are used.

Stukenholtz Laboratory, Inc.

Fertilizer recommendations are based on university guidelines using specific crop needs, yield goals, previous crop, organic matter and soil analysis.

University of Idaho, Analytical Sciences Laboratory

No recommendations from lab—customers are referred to county Extension agents or industry field representatives.

Western Testing Laboratory, Inc.

A budget approach for N recommendations considers yield goal, crop, soil analysis and organic matter release. P and K recommendations are based on soil analysis and yield goal.

Methods of soil analysis

Nitrogen (N)

Total N is determined on Kjeldahl digests by titration, steam distillation and colorimetry and by Auto-Analyzer methodologies. Calcium sulfate ($CaSO_4$), sodium chloride (NaCl) and potassium chloride (KCl) extracting solutions are used in ammonium-N (NH_4-N) analysis. Methodologies include: electrode, steam distillation with titration and Auto-Analyzer. Nitrite-N (NO_2-N) and nitrate-N (NO_3-N) are determined on water, calcium sulfate ($CaSO_4$) and calcium hydroxide ($Ca(OH)_2$) extracts with an electrode, cadmium reduction with Auto-Analyzer, phenoldisulfonic acid and chromotropic acid.

Phosphorus (P)

Phosphorus determinations are made from sodium acetate, Bray, sodium bicarbonate (Olsen), ammonium bicarbonate-DTPA, Morgan extracting solutions and a water-based method. Colorimetric methods include ascorbic acid and the Fiske-Subbarrow on spectrophotometers and Auto-Analyzer and through inductively coupled plasma spectrophotometry (ICP) techniques. The soil-to-extracting solution ratio ranges from 1:20 to 1:50.

Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na)

Elemental analyses on water, ammonium acetate, ammonium bicarbonate-DTPA and sodium acetate (only K, Ca, Mg) extracts are determined by atomic absorption spectrophotometry (AA) and by ICP.

Sulfur (S)

Determinations of total S following nitric-perchloric digestion are made by ICP, infrared and high-temperature combustion furnace analyzers. Inorganic-S (SO_4-S) is found after ammonium acetate, water and monocalcium phosphate extractions with ICP, turbidimetric and gravimetric methods. Organic-S is calculated by difference.

Zinc (Zn), Manganese (Mn), Copper (Cu), Iron (Fe), Boron (B), Molybdenum (Mo)

DTPA and ammonium bicarbonate-DTPA extracting solutions are being used for analysis of Zn, Mn, Cu, Fe, B and Mo by AA and ICP. B is also determined from hot water extracts using a colorimetric method. An ammonium oxalate and ammonium bicarbonate-DTPA extracting solutions are used for Mo analysis.

Organic Matter (OM)

Total carbon (C) concentrations are determined after combustion. The Walkley-Black method is the most popular technique for organic matter analysis. Loss on ignition is a method increasing in popularity.

pH, Electrical Conductivity (EC)

Soil pH and electrical conductivity are determined from saturated pastes, 1:1 and 1:2 soil to water ratios, using an electrode and conductivity bridge, respectively.

Cation Exchange Capacity (CEC)

CEC measurements are determined from a summation of the cations from ammonium acetate extraction after sodium saturation following AA and Auto-Analyzer techniques.

Plant Analysis Services

Plant analysis

Analysis of plant samples is an effective means of evaluating the nutritional status of a crop, since the nutrient concentration in the plant correlates to the nutrient-supplying capacity of the soil. Plant analysis is used to complement and refine nutrient recommendations, not replace routine soil fertility analysis programs. Soil analysis is not perfect, so plant analysis provides good supplementary information. Plant analysis results are usually "after the fact" and serve as a means to improve future nutrient programs. Sulfur and micronutrient deficiencies are readily identified through plant analysis, while soil analysis may not be as definitive for these elements. Plant analysis is also used to identify hidden trouble, confirm visual symptoms, manage crop quality, locate marginally deficient areas and provide information on nutrient uptake and utilization. Most of the surveyed laboratories provided similar plant analysis services (Table 5). The variety in methodology with soil analysis services is not as much of a problem with plant analysis.

Some people use the terms "plant tissue analysis" and "plant analysis" interchangeably, but a distinction should be made between these two techniques. Plant tissue analysis (often called a "quick test") consists of field nutrient evaluation with fresh plant samples using test kits. In general, plant sap is qualitatively (low,

Table 5. Summary of plant analysis services offered to Montana producers by laboratory.

Element/ Method or Compound	Agvise Labs	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soiltest Farm Consultants	Stukenholtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Nitrogen (N)	x	x	x	x	x	x	x	x	x	x	x	x
Nitrate-N (NO_3-N)	x	x	x	x	x	x	x	x	x	x	x	x
Phosphorus (P)	x	x	x	x	x	x	x	x	x	x	x	x
Potassium (K)	x	x	x	x	x	x	x	x	x	x	x	x
Calcium (Ca)	x	x	x	x	x	x	x	x	x	x	x	x
Magnesium (Mg)	x	x	x	x	x	x	x	x	x	x	x	x
Sulfur (S)	x	x	x	x	x	x	x	x	x	x	x	x
Zinc (Zn)	x	x	x	x	x	x	x	x	x	x	x	x
Manganese (Mn)	x	x	x	x	x	x	x	x	x	x	x	x
Copper (Cu)	x	x	x	x	x	x	x	x	x	x	x	x
Iron (Fe)	x	x	x	x	x	x	x	x	x	x	x	x
Boron (B)	x	x	x	x	x	x	x	x	x	x	x	x
Molybdenum (Mo)			x		x	x		x			x	
Chloride (Cl)	x	x	x	x		x		x	x	x	x	x

medium or high) analyzed for NO_3-N, PO_4-P and K concentrations. Plant analysis is conducted in an analytical laboratory producing accurate, complete quantitative results that can be compared to developed standards. Plant nutrient levels are affected by plant part sampled, plant growth stage, nutrient interactions, soil moisture stress, soil aeration, environmental conditions, planting pattern, plant population, variety and hybrid. Plant diseases, insects and other external factors will also affect plant nutrient levels. Guidelines for the proper plant part to be sampled, growth stage and critical nutrient ranges for several crops are presented in Table 6. From a practical standpoint, the critical nutrient range is defined as the level of a nutrient below which crop yield, quality or performance is unsatisfactory.

Plant analysis provides useful information, provided standard or reference samples are available and proper collection and analysis procedures are followed. The analytical results from annual crops may not be useful during the current growing season, but may be helpful for future crops. Plant analysis of perennial crops may indicate nutrient deficiencies that can be corrected, depending on the plant growth stage and the deficient nutrient.

Plant analysis units

Plant analysis units are readily convertible to common units (Table 7). The standard convention generally is ppm for numerical values between 0 and 100 and percent for higher values. One part per million (ppm) is equivalent to one microgram per gram (µg/g) and 1 percent is equal to 10,000 ppm.

Plant analysis packages

Laboratory	Cost
Agvise Laboratories	$25
Total N, P, K, Ca, Mg, S, Zn, Mn, Cu	
Astro-Chem Lab, Inc.	
No plant analysis available.	
B & C Ag Consultants	$17
Total N or NO_3-N plus recommendation for wheat/barley stems, corn leaves, beet/potato petioles. Thirteen other analyses available at $4 -$12 per test.	

Table 6. Plant sampling guidelines and critical nutrient ranges for several Montana crops.

Crop	Plant part	Growth stage	Critical nutrient concentration
Alfalfa	upper 1/3 to 1/2 of tops	1/10 of bloom	none for NO_3-N 0.2 to 0.3% P 1.0 to 1.8% K
Conifers	upper crown	autumn to late autumn	1.3 to 4.0% N 0.1 to 0.3% P 0.5 to 1.0% K
Potatoes	recently mature petiole 4 or 5 from top	early tuber set 50-60 days	1.5 to 1.8% N 0.14 to 0.16% PO_4-P
Small Grains	above-ground portion	head emergence	1.75% to 3.0% N 0.2 to 0.5% P 1.5 to 3.0% K
Sugarbeets	petiole from most recently matured leaves	4 to 6 weeks	1000 ppm NO_3-N 750 ppm PO_4-P 1000 ppm K
Tall Fescue	whole tops	5 to 6 weeks between cuts	2.8 to 3.4% N 0.26 to 0.32% P 2.5 to 2.8% K

Energy Laboratories, Inc.
No package available. Individual tests cost $7–$20.

Harris Laboratories, Inc. $22
N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, B, Al, Na

Maxim Technologies, Inc. Per Quote
Total N, P, metals

Midwest Laboratories, Inc. $18
N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, B, Al, Na

MVTL Laboratories, Inc. $32
N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, B

Sathe Analytical Laboraotry, Inc.
No package available, nine individual tests are available at $5-$15 per test.

Soil Testing Laboratory, North Dakota State University
No plant analysis available.

Soiltest Farm Consultants, Inc. $38
NO_3-N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, B

Stukenholtz Laboratory, Inc. $35
NO_3-N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, B

University of Idaho, Analytical Sciences Laboratory $66
NO_3-N, P, K, Ca, Mg, S, Zn, Mn, Cu, Fe, Mo, Al, Cd, Co, Cr, Na, Ni, Pb

Western Testing Laboratory, Inc.
No package available, eleven individual tests are available, $10 for the first test and $3 for each additional test.

Table 7. Summary of plant analysis units offered to Montana producers by laboratory.

Element/ Method or Compound	Agvise Labs	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soiltest Farm Consultants	Stukenholtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Nitrogen (N)	%	%	µg/g	%	ppm	%	%	ppm	%	%	%	%
Nitrate-N (NO_3-N)	ppm	ppm	µg/g	ppm		%, ppm	%, ppm	ppm	µg/g	ppm	µg/g	%, ppm
Phosphorus (P)	ppm	%	µg/g	%	ppm	%	%	ppm	%	%	µg/g	%
Potassium (K)	%	%	µg/g	%	ppm	%	%	ppm	%	%	µg/g	%
Calcium (Ca)	%	%	µg/g	%	ppm	%	%	ppm	%	%	µg/g	%
Magnesium (Mg)	%	%	µg/g	%	ppm	%	%	ppm	%	%	µg/g	%
Sulfur (S)	%	%	µg/g	%		%	%	ppm	%	%	µg/g	%
Zinc (Zn)	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Manganese (Mn)	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Copper (Cu)	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Iron (Fe)	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Boron (B)	ppm	ppm	µg/g	ppm	ppm	ppm	ppm	ppm	µg/g	ppm	µg/g	ppm
Molybdenum (Mo)			µg/g	ppm	ppm	ppm		ppm			µg/g	
Chloride (Cl)	%	ppm	µg/g	ppm		ppm		ppm	µg/g	%	µg/g	ppm

Methods of plant analysis

Nitrogen (N)

TKN (does not include NO_3-N) for plant analysis is accomplished from a sulfuric acid digest with Kjeldahl catalyst addition by titration and Auto-Analyzer techniques. Plant tissue nitrate-N (NO_3-N) concentration is measured with a specific ion electrode.

P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, Mo

Wet ashing with nitric-perchloric acids and dry ashing are commonly used on all elements for sample preparation, with analysis by emission, AA and ICP spectrophotometry. N and P are also colorimetrically determined. B techniques also include colorimetric analysis.

Sulfur (S)

S methodologies include nitric-perchloric acids for total S and dry ashing with magnesium nitrate addition by infrared, ICP and turbidimetric procedures.

Water Analysis Services

Water analysis

Surveyed laboratories provide water analysis services to determine suitability of samples for domestic, livestock and irrigation purposes (Table 8). Common contaminants and problems with water quality in ground and surface waters in Montana include: alkalinity, salinity, fluoride, sodium, arsenic, nitrate, selenium, total dissolved solids, pH, iron, disease organisms, pesticides, heavy metals, other elements and other chemicals. Prior to water sample collection, specific directions and guidelines should be obtained from one of the following: Montana Department of Environmental Quality, Montana Department of Agriculture, Montana Veterinary Diagnostic Laboratory, Montana State Soil, Plant and Water Analytical Laboratory, Montana Bureau of Mines and Geology, and the Chemistry Station Analytical Lab.

Two types of national drinking water regulations exist. Primary regulations are enforceable and when exceeded, constitute a health hazard for people. Secondary

Table 8. Summary of water analysis services offered to Montana producers by laboratory.

Analysis	Agvise Labs	Astro-Chem Lab	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Lab, NDSU	Soiltest Farm Consultants	Stukenholtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Total dissolved solids	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Suspended solids	x	x	x	x		x	x	x	x		x	x	x	
Sodium adsorption ratio (SAR)	x	x	x	x	x	x	x	x	x		x	x	x	x
Electrical conductivity (EC)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
pH	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nitrate-N (NO_3-N)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Heavy metals		x		x		x	x	x	x	x	x	x	x	

regulations are guidelines for the aesthetic quality of water, such as color, odor and taste. Test results higher than these guidelines (Tables 9, 10 and 11) indicate water contamination or unsuitable levels of specific elements. Professionals should be contacted when high contaminant levels are encountered.

Water analysis units

Reported units of mg/l, ppm and µg/ml are all equivalent (Table 12).

Several general relationships are frequently used to convert one unit to another:

Salt concentration (mg/l) = 640 x EC (mmhos/cm, dS/m or mS/cm)

Total cation concentration (meq/l) = 10 x EC (mmhos/cm, dS/m or mS/cm)

Conductivity units for water analysis are generally in µmhos/cm due to

Table 9. Drinking water quality standards for domestic suitability.

Contaminant	Concentration (ppm)
Maximum allowable contaminant levels	
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Cr)	0.05
Lead (Pb)	0.05
Mercury (Hg)	0.002
Nitrate-N (NO_3-N)	10.0
Selenium (Se)	0.01
Silver (Ag)	0.05
Fluoride (F)	2.4
Secondary levels	
Copper (Cu)	1.0
Zinc (Zn)	5.0
Iron (Fe)	0.3
Manganese (Mn)	0.05
Chloride (Cl)	250
Sulfate-S (SO_4-S)	250
Total dissolved solids (TDS)	500
pH	6.5 to 8.5

Table 10. Drinking water quality standards for livestock suitability.

Contaminant	Upper Concentration Limit (ppm)
Aluminum (Al)	5
Arsenic (As)	0.2
Boron (B)	5
Cadmium (Cd)	0.05
Chromium (Cr)	1.0
Cobalt (Co)	1.0
Copper (Cu)	0.5
Fluoride (F)	2.0
Lead (Pb)	0.05
Mercury (Hg)	0.01
Nitrate + Nitrite-N (NO_3+NO_2-N)	100
Nitrite (NO_2)	10
Selenium (Se)	0.05
Vanadium (V)	0.10
Zinc (Zn)	24
Total dissolved solids	10,000
Magnesium and sodium sulfates	5,000
Alkalinity (carbonate + bicarbonate)	2,000

Table 11. Water quality standards for irrigation suitability.

	Degree of problem		
Constituent	**None**	**Increasing**	**Severe**
Electrical conductivity (EC, mmhos/cm)	< 0.75	0.75 to 3	> 3
Permeability, low salt water (EC, mmhos/cm)	> 0.5	0.5 to 0.2	< 0.2
Sodium hazard (adjusted SAR)			
Montmorillonitic	< 6	6 to 9	> 9
Illite-vermiculitic	< 8	8 to 16	> 16
Kaolinite-sesquioxidic	< 16	16 to 24	> 24
Specific ion toxicity			
Sodium (adjusted SAR)	< 3	3 to 9	> 9
Chloride (ppm)	< 142	142 to 355	> 355
Boron (ppm)	< 0.75	0.75 to 2	> 2
Miscellaneous effects			
Nitrate (ppm)	< 5	5 to 30	> 30
Bicarbonate	< 92	92 to 520	> 520
pH	Normal range 6.5 to 8.5		

Table 12. Summary of water analysis units reported to Montana producers by laboratory.

Analysis	Agvise Labs	Astro-Chem Lab	B & C Ag Consultants	Energy Labs	Harris Labs	Maxim Tech	Midwest Labs	MVTL Labs	Sathe Analytical Lab	Soil Testing Lab, NDSU	Soiltest Farm Consultants	Stukenholtz Lab	Univ. of ID Analytical Sciences Lab	Western Testing Lab
Total dissolved solids	ppm	mg/l	ppm	mg/l	ppm	ppm	mg/l	mg/l	mg/l	mg/l	µg/ml	mg/l	mg/l	ppm
Suspended solids	ppm	mg/l	mg/l	mg/l		ppm	mg/l	mg/l	mg/l	mg/l	µg/ml	mg/l	mg/l	
Electrical conductivity (EC)	mmhos/cm	µmhos/cm	mmhos/cm	µmhos/cm	mmhos/cm	mmhos/cm	mmhos/cm	µmhos/cm	µmhos/cm	µmhos/cm, dS/l	mmhos/cm µmhos/cm	µmhos/cm	µmhos/cm	mmhos/cm
Nitrate-N (NO_3-N)	ppm	mg/l	ppm	mg/l	ppm	ppm	mg/l	mg/l	mg/l	ppm	mg/l, µg/ml	ppm	mg/l	ppm
Heavy Metals		mg/l		mg/l		ppm	mg/l	mg/l, µg/l	mg/l, mmhos/cm	ppm	ppb, µg/l	ppm	mg/ml, µg/ml	

the lower salt concentrations present in most waters. Equivalent units for salt concentrations are mmhos/cm and mS/cm with 1,000 µmhos/cm equal to 1 mmhos/cm, dS/m or mS/cm. Heavy metal concentrations are reported in ppm or ppb (parts per billion) with 1 ppm equivalent to 1,000 ppb.

Water analysis packages

Laboratory — **Cost**

Agvise Laboratories

Domestic suitability: $57
Ca, Mg, Na, Fe, Mn, nitrate, sulfate, pH, electrical conductivity, total dissolved solids, hardness, total coliform bacteria (MPN); individual tests available

Irrigation suitability: $28
Ca, Mg, Na, pH, electrical conductivity, total dissolved solids, SAR, sodium hazard, salinity hazard

Astro-Chem Lab, Inc.

Irrigation/Domestic suitability: $40
Ca, Mg, K, Na, Fe, Cl, nitrate, sulfate, carbonate, bicarbonate, pH, electrical conductivity, SAR, total dissolved solids, hardness

B & C Ag Consultants

Livestock suitability: $20
Ca, Mg, Na, nitrate, sulfate, pH, electrical conductivity, total dissolved solids

Irrigation suitability: $25
Ca, Mg, K, Na, carbonate, bicarbonate, pH, electrical conductivity, SAR, total dissolved solids

Energy Laboratories, Inc.

Domestic suitability: $79.50
Ca, Mg, K, Na, Fe, Cl, nitrate + nitrite as N, sulfate, pH, electrical conductivity, total dissolved solids, alkalinity; tests for radiochemicals available for additional charge

Livestock suitability: $27.50
Nitrate + nitrite as N, sulfate, total dissolved solids, alkalinity

Irrigation suitability: $26
Ca, Na, electrical conductivity, SAR

Harris Laboratories, Inc.

Irrigation suitability: $46
Ca, Mg, K, Na, B, Cl, nitrate, sulfate, carbonate, bicarbonate, phosphate, pH,

electrical conductivity, SAR, total soluble salts, total hardness

Maxim Technologies, Inc.
Domestic suitability: $80
Ca, Mg, K, Na, Fe, Mn, Cl, F, nitrate + nitrite as N, sulfate, pH, electrical conductivity, alkalinity, total dissolved solids

Irrigation suitability: $33
Ca, Mg, Na, B, electrical conductivity, SAR

Livestock suitability: $159
B, Cu, F, Zn, nitrate + nitrite-N, aluminum, arsenic, cadmium, chromium, cobalt, lead, mercury, selenium, vanadium, nitrite, magnesium and sodium sulfates, total dissolved solids, alkalinity

Midwest Laboratories, Inc.
Domestic suitability: $40
Ca, Mg, Na, Fe, Mn, Cl, F, nitrate-N, sulfate, pH, electrical conductivity, total dissolved solids (by calculation), hardness, purity (total coliform)

Livestock suitability: $30
Ca, Mg, Na, Fe, Cu, Cl, nitrate-N, sulfate, pH, electrical conductivity, total dissolved solids (by calculation)

Irrigation suitability: $38
Ca, Mg, K, Na, P, B, Cl, sulfate, nitrate-N, carbonate, bicarbonate, pH, electrical conductivity, SAR, total dissolved solids (by calculation)

MVTL Laboratories, Inc.
Routine suitability: $40
Ca, Mg, Na, Fe, Mn, nitrate, pH, electrical conductivity, SAR, total dissolved solids (calculated), hardness

Irrigation suitability: $25
Ca, Mg, Na, electrical conductivity, SAR, total dissolved solids

Sathe Analytical Laboratory, Inc.
Drinking/Irrigation/Livestock suitability: $40
Ca, Mg, K, Na, Fe, Cl, nitrate, sulfate, carbonate, bicarbonate, pH, electrical conductivity, SAR, total dissolved solids, hardness, specific gravity, relative sodium concentration

Soil Testing Laboratory, North Dakota State University
Irrigation suitability: $25
SAR, total dissolved solids, hardness

Soiltest Farm Consultants, Inc.
Irrigation water suitability: $66
Ca, Mg, K, Na, Cl, P, nitrate, sulfate, pH, electrical conductivity, SAR, hardness, alkalinity, classification

Stukenholtz Laboratory, Inc.
Irrigation suitability: $50
Ca, Mg, K, Na, B, P, Cl, nitrate, sulfate, carbonate, bicarbonate, pH, SAR, hardness, salts

University of Idaho, Analytical Sciences Laboratory
Domestic/Livestock suitability: $85
Ca, Mg, K, Na, Cu, Fe, Mo, Zn, Cl, nitrate, sulfate, phosphate, pH, electrical conductivity, SAR, total dissolved solids, hardness, alkalinity

Irrigation suitability: $60
Ca, Mg, K, Na, Cl, nitrate, sulfate, phosphate, pH, electrical conductivity, SAR, hardness, alkalinity

Western Testing Laboratory, Inc.
Livestock suitability: $25
Ca, Mg, K, Na, Cu, nitrate, sulfate, pH, electrical conductivity, total dissolved solids

Irrigation suitability: $25
Ca, Mg, K, Na, carbonate, bicarbonate, pH, electrical conductivity, SAR, total dissolved solids

Methods of water analysis

Suspended solids are determined gravimetrically. Adjusted SARs are calculated from Ca, Mg, K and Na values determined from AA and ICP. Electrical conductivity is measured with a conductivity bridge and pH is measured with an electrode. Soluble salt concentration is calculated in one of two ways—with electrical conductivity measurements or determined from dissolved cations. Nitrate concentrations are found with an electrode, cadmium reduction, then Auto-Analyzer, phenoldisulfonic acid and ion chromatography. Atomic adsorption and ICP spectrophotometry are used for heavy metal analysis.

Contact Personnel

Bob Deutsch or John Lee
Agvise Laboratories
P.O. Box 510, HWY 15
Northwood, ND 58267-0510
701-587-6010

Christina Hagen or Bruce Kyllo
Astro-Chem Lab, Inc.
P.O. Box 972
Williston, ND 58802-0972
701-572-7355

Ray Choriki
B&C Ag Consultants
315 South 26th Street
P.O. Box 1184
Billings, MT 59103
406-259-5779

John Standish
Energy Laboratories, Inc.
P.O. Box 30916
Billings, MT 59107
406-252-6325
800-735-4489

Steve Frack
Harris Laboratories, Inc.
621 Rose Street
P.O. Box 80837
Lincoln, NE 68501
402-476-2811

Kathy Smit
Maxim Technologies, Inc.
600 South 25th Street
P.O. Box 30615
Billings, MT 59107
406-248-9161

John Menghini
Midwest Laboratories, Inc.
13611 B Street
Omaha, NE 68144
402-334-7770

Larry Wikoff — Soil and Plant Analysis
MVTL Laboratories, Inc.
710 South 14th Street
P.O. Box 1104
Grand Forks, ND 58201
800-272-7645

Rod Reetz — Water quality
MVTL Laboratories, Inc.
1411 South 12th Street
Bismarck, ND 58504
800-279-6885

Neal Falk
Sathe Analytical Laboratory, Inc.
P.O. Box 1527
Williston, ND 58801
701-572-3632

Larry Swenson
Soil Testing Laboratory
North Dakota State University
103 Waldron Hall
P.O. Box 5575
Fargo, ND 58105-5575
701-231-8942

Brent Thyssen or Dan Nelson
Soiltest Farm Consultants, Inc.
2925 Wapato Drive
Moses Lake, WA 98837
509-765-1622
800-764-1622

Dale Stukenholtz
Stukenholtz Laboratory, Inc.
P.O. Box 353
Addison Avenue East
Twin Falls, ID 83303
208-734-3050
800-759-3050

University of Idaho
Analytical Sciences Laboratory
Holm Research Center
Moscow, ID 83844-2201
208-885-7081

Bob Thoroughman
Western Testing Laboratory, Inc.
1920 9th Avenue North
P.O. Box 3165
Great Falls, MT 59403
406-761-1724
888-862-1724

This publication is based on Bulletin 1349 by
J. S. Jacobsen, T. G. Moore and J. W. Bauder

The programs of the Montana State University Extension Service are available to all people regardless of race, creed, color, sex, disability or national origin. Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Charles H. Rust, Interim Dean and Director, Montana State University Extension Service, Bozeman, Montana 59717.

4522000198 MS

Soil, Plant and Water Analytical Laboratories for Montana Agriculture

EB 150, Issued January 1998

Replaces Bulletin 1349