Comparative Analysis of Soil Amendment Materials:

Nutrient Solubility and Delivery Characteristics

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Executive Summary

This report analyzes three soil amendment materials to evaluate their effectiveness in delivering nutrients to plants through water-soluble pathways, with primary focus on calcium availability and supplementary analysis of magnesium, iron, manganese, and other essential nutrients. Water solubility testing was conducted by crushing materials, agitating in solution, and measuring dissolved nutrients after equilibration. These results were compared to total nutrient content to determine the percentage of each nutrient available for immediate plant uptake.

Key Findings:

Calcium Delivery - Primary Finding: Lake Bonneville Marl demonstrates dramatically superior calcium solubility (2.95%) compared to Common Limestone (0.28%), representing a 10.5× improvement in immediate calcium availability. Despite having similar total calcium content (~21%), Lake Bonneville Marl delivers substantially more water-soluble calcium to plant roots. The Dolomitized version, while having reduced total calcium (10.54%), still maintains better solubility (1.90%) than Common Limestone, offering 6.8× more immediate calcium delivery (Stukenholtz, December 2025).

Secondary Macronutrients and Micronutrients: Lake Bonneville Marl shows 28× higher magnesium solubility than Common Limestone, while the Dolomitized material provides exceptional iron availability (69 ppm soluble from 13,134 ppm total) and outstanding manganese content (441 ppm total, 2 ppm soluble). Both Lake Bonneville materials deliver 15-17× more water-soluble boron than Common Limestone (Stukenholtz, December 2025).

Critical Sodium Consideration: Lake Bonneville Marl's superior calcium delivery comes with high sodium content (3.75% total, 79.5% solubility) and elevated salinity (EC 26.2)(Stukenholtz, December 2025), requiring careful management for salt-sensitive crops. While this sodium content is beneath the 5% base saturation threshold typically considered safe in agricultural soils, the sodium content of the soil this amendment is applied to will need to be taken into consideration. The Dolomitized version significantly reduces this concern (0.67% total sodium) while maintaining enhanced calcium solubility compared to Common Limestone. It should be noted that this sodium content is an anomaly as all other samples we have taken throughout the basin have had a total sodium content between 0.3% and 0.6%.

Materials Tested

1. Common Limestone (Reports #161435 and #5321, Stukenholtz, December 2025 and January 2026)

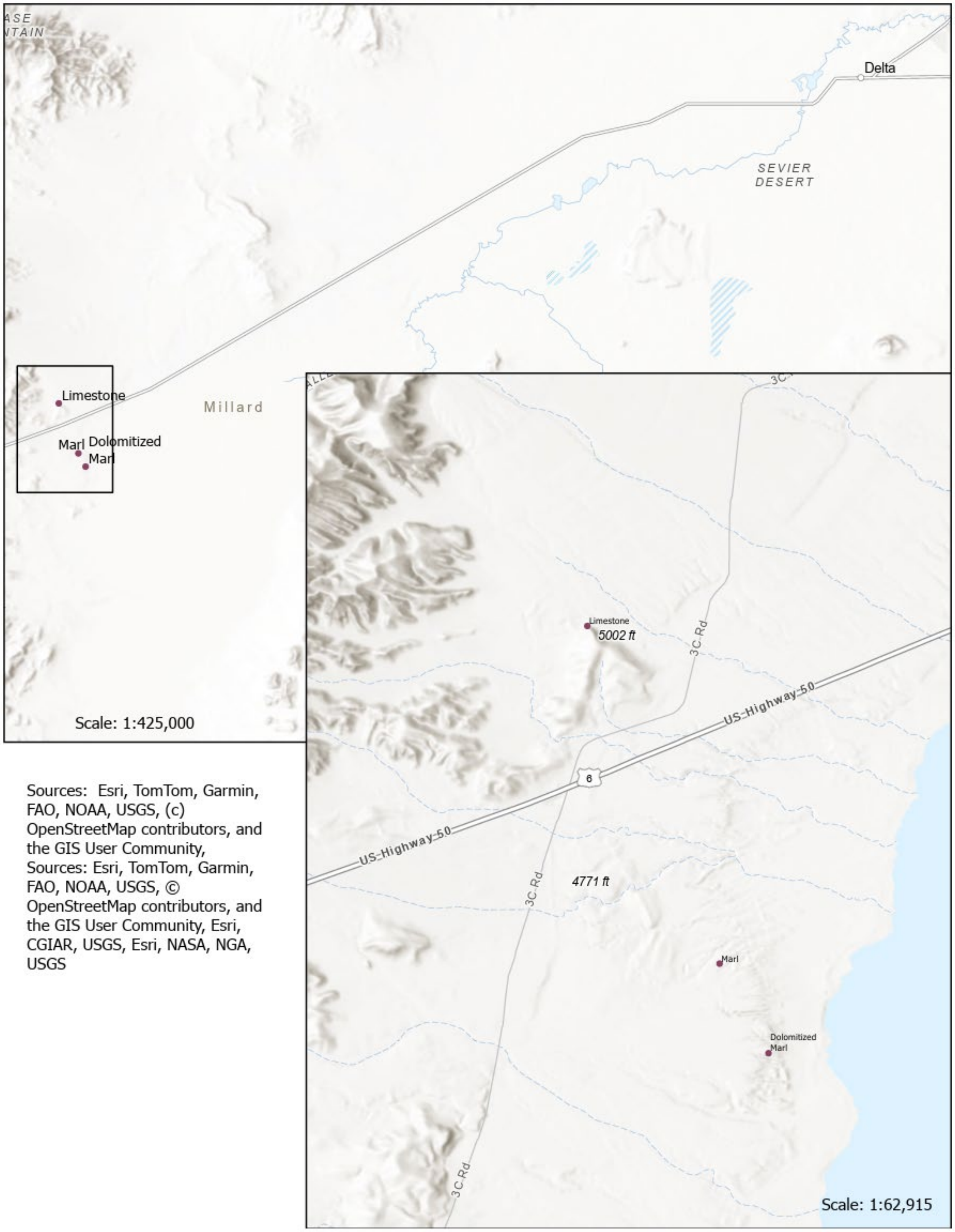
Local common micritic limestone material serving as the control baseline for comparison.

2. Lake Bonneville Marl (Reports #161436 and #5320, Stukenholtz, December 2025 and January 2026)

Material sourced from ancient Lake Bonneville sediments, characterized by a unique mineral composition.

3. Dolomitized Lake Bonneville Marl (Reports #161437 and #5319, Stukenholtz, December 2025 and January 2026)

Geologically altered version with increased magnesium content through dolomitization, featuring dramatically elevated iron and manganese levels.



Map 1: Location map of samples taken for this analysis.

Methodology

Testing Protocol (derived from phone conversation with Stukenholtz Laboratory in December, 2025):

Compost Analysis: Complete nutrient characterization of raw materials determining total available nutrient content through standard extraction and analysis procedures.

Water Soluble Test: Materials were crushed to uniform particle size, suspended in water, agitated for a standardized duration, allowed to equilibrate, and analyzed for dissolved nutrients. This simulates the nutrients immediately available to plant roots in soil solution.

Calculation: Solubility percentage = (Water Soluble Concentration ÷ Total Nutrient Content) × 100. This metric indicates what fraction of each nutrient can be rapidly delivered to plants through soil water.

Detailed Nutrient Solubility Analysis

The following section presents nutrient solubility data organized by priority, beginning with calcium as the primary nutrient of concern, followed by other secondary macronutrients and micronutrients critical for plant health.

Calcium (Ca) - Primary Nutrient of Concern

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	21.18	0.059	0.28
Lake Bonneville Marl	21.04	**0.62**	**2.95**
Dolomitized LB Marl	10.54	0.20	1.90

Table 1: Calcium bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Critical Analysis:

Absolute Calcium Delivery: Lake Bonneville Marl delivers 0.62% water-soluble calcium compared to only 0.059% from Common Limestone—representing a 10.5× increase in immediately available calcium. For a typical application rate of 2 tons per acre, Lake Bonneville Marl would provide approximately 24.8 lbs of water-soluble calcium versus 2.4 lbs from Common Limestone.

Solubility Efficiency: Despite both Common Limestone and Lake Bonneville Marl containing approximately 21% total calcium, the Lake Bonneville material releases calcium into solution far more readily (2.95% solubility vs 0.28%). This suggests fundamental differences in calcium mineralogy—Common Limestone's calcium is predominantly locked in highly stable calcite ($CaCO_3$) structures, while Lake Bonneville Marl likely contains more readily soluble calcium salts or less crystalline calcium carbonate forms.

Dolomitized Material Trade-offs: The dolomitization process replaces approximately 50% of the calcium with magnesium, reducing total calcium from 21.04% to 10.54%. However, the resulting material maintains 1.90% solubility—still 6.8× higher than Common Limestone. This provides 0.20% water-soluble calcium, which is 3.4× more than Common Limestone despite having half the total calcium content.

Practical Implications: For calcium-deficient soils or crops with high calcium demands (tomatoes, peppers, apples, lettuce), Lake Bonneville Marl offers superior immediate calcium delivery. The rapid solubility addresses acute calcium deficiency symptoms more effectively than Common Limestone's slow-release profile. However, the 10× difference in solubility also means Lake Bonneville Marl's calcium reserves will be depleted more quickly, potentially requiring more frequent reapplication. The choice between materials depends on whether immediate calcium availability or long-term sustained release is the priority.

Supplementary Nutrients (P, K)

Phosphorus (P_2O_5):

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	0.07	0.003	4.29
Lake Bonneville Marl	0.07	0.002	2.86
Dolomitized LB Marl	0.12	0.003	2.50

Table 2: P_2O_5 bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

All three materials show very low phosphorus solubility (2.5-4.3%), which is typical for mineral-based amendments. Phosphorus naturally binds strongly to soil particles and dissolves slowly. These materials will provide long-term, sustained phosphorus release rather than immediate availability. For crops requiring rapid phosphorus supplementation, water-soluble fertilizers would be necessary in addition to these amendments.

Potassium (K_2O):

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	0.09	0.059	65.56
Lake Bonneville Marl	0.24	0.100	41.67
Dolomitized LB Marl	0.47	0.088	18.72

Table 3: K_2O bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Potassium shows dramatically different solubility patterns. Common Limestone exhibits exceptional K solubility at 65.56%, despite having the lowest total K content. This high release rate makes it excellent for immediate potassium delivery. Lake Bonneville Marl has higher total K (0.24%) with moderate solubility (41.67%), providing both immediate and sustained release. The Dolomitized material, despite having the highest total K content (0.47%), shows the lowest solubility at 18.72%, suggesting it would provide long-term potassium availability rather than rapid delivery.

Secondary Macronutrients (Ca, Mg, S)

Magnesium (Mg):

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	2.10	0.005	0.24
Lake Bonneville Marl	0.99	0.066	6.67
Dolomitized LB Marl	2.47	0.038	1.54

Table 4: Magnesium bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Magnesium shows the most dramatic variation in solubility. Lake Bonneville Marl demonstrates 28× higher Mg solubility (6.67%) than Common Limestone (0.24%), making it far superior for immediate magnesium delivery despite having lower total Mg content. The Dolomitized material has the highest total Mg (2.47%) but relatively low solubility (1.54%), providing a reservoir for long-term sustained release. The contrast between Lake Bonneville materials highlights how dolomitization trades immediate Mg availability for increased total content and sustained release.

Sulfur (S):

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	0.19	0.003	1.58
Lake Bonneville Marl	0.54	0.30	55.56
Dolomitized LB Marl	0.31	0.23	74.19

Table 5: Sulfur bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Sulfur solubility varies dramatically among materials. Lake Bonneville Marl shows excellent sulfur solubility at 55.56%, while the Dolomitized version exhibits exceptional solubility at 74.19%, making both materials excellent sources of immediately available sulfur. Common Limestone provides minimal sulfur availability (1.58%). For crops with high sulfur requirements, the Lake Bonneville materials offer substantial advantages over traditional limestone amendments.

Sodium (Na) - Critical Consideration

Material	Total (%)	Soluble (%)	Solubility (%)
Common Limestone	0.00	0.009	Trace
Lake Bonneville Marl	3.75	2.98	**79.47**
Dolomitized LB Marl	0.67	0.45	67.16

Table 6: Sodium bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

CONCERN: The Lake Bonneville Marl sample contains high sodium levels (3.75% total, 2.98% soluble) with 79.47% solubility. This represents a 331× increase in soluble sodium compared to Common Limestone. This is not typical as all other samples we have had tested throughout the region have had between 0.3% and 0.6% total sodium content. High sodium can cause soil structure degradation, reduced water infiltration, and direct toxicity to many crops. The elevated salinity (EC 26.2) further compounds these concerns. This material should only be used in sodium-tolerant crops or where sodium levels are carefully monitored and managed through leaching. Blending with other materials may reduce the sodium to more easily managed levels. The Dolomitized version reduces total sodium to 0.67% with 0.45% soluble, which is a significant improvement but still 50× higher than Common Limestone. Due to the low concentrations seen elsewhere in the region, this seems to be an anomalous result, but highlights the need for periodic testing to monitor nutrient levels.

Micronutrients - Iron and Manganese

Iron (Fe):

Material	Total (ppm)	Soluble (ppm)	Solubility (%)
Common Limestone	1,965	22	1.12
Lake Bonneville Marl	4,979	0.1	0.002
Dolomitized LB Marl	**13,134**	69	0.53

Table 7: Iron bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Iron shows remarkable characteristics in the Dolomitized material, which contains an extraordinary 13,134 ppm total iron (6.7× higher than Common Limestone). Despite this massive iron reservoir and very low solubility (0.53%), it still provides 69 ppm soluble iron, which is 3× more than Common Limestone. This makes the Dolomitized material uniquely valuable for iron-deficient soils or crops with high iron requirements. Lake Bonneville Marl paradoxically has high total iron but virtually no solubility, making it ineffective as an iron source despite containing 4,979 ppm.

Manganese (Mn):

Material	Total (ppm)	Soluble (ppm)	Solubility (%)
Common Limestone	103	0.65	0.63
Lake Bonneville Marl	**198**	0.42	0.21
Dolomitized LB Marl	**441**	**2.0**	0.45

Table 8: Manganese bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Manganese content follows a similar pattern to iron in the Lake Bonneville materials. The Dolomitized version contains 441 ppm total manganese (4.3× higher than Common Limestone) and delivers 2.0 ppm in water-soluble form—3× more than Common Limestone's 0.65 ppm. Lake Bonneville Marl has intermediate total Mn (198 ppm) but the lowest solubility (0.21%), providing less immediately available manganese (0.42 ppm) than Common Limestone despite nearly double the total content. The Dolomitized material is clearly superior for manganese supplementation, offering both high total reserves and reasonable immediate availability.

Other Micronutrients

Boron (B):

Material	Total (ppm)	Soluble (ppm)	Solubility (%)
Common Limestone	1.05	0.35	33.33
Lake Bonneville Marl	**16.0**	**4.0**	25.00
Dolomitized LB Marl	**20.0**	**6.0**	30.00

Table 9: Boron bulk nutrient content and dissolved nutrient content, input from Stukenholtz, December 2025 and January 2026 lab results.

Boron content and availability show dramatic differences. Both Lake Bonneville materials contain 15-19× more total boron than Common Limestone, with the Dolomitized version having 20 ppm total and 6 ppm soluble. This provides 17× more water-soluble boron than Common Limestone, making these materials exceptional boron sources. However, boron toxicity can occur, so application rates must be carefully calculated based on crop tolerance and existing soil boron levels.

Comprehensive Solubility Comparison

The following table summarizes solubility percentages for all nutrients across all materials, enabling direct comparison of nutrient delivery characteristics.

Nutrient	Common Limestone (%)	Lake Bonneville (%)	Dolomitized (%)
P2O5	4.29	2.86	2.50

K2O	65.56	41.67	18.72
Ca	0.28	2.95	1.90
Mg	0.24	6.67	1.54
S	1.58	55.56	74.19
Na	N/A	79.47	67.16
Zn	0.90	1.00	0.91
Fe	1.12	0.00	0.53
Mn	0.63	0.21	0.45
Cu	20.00	6.80	3.00
B	33.33	25.00	30.00

Table 10: Summary of solubility percentages, input from Stukenholtz, December 2025 and January 2026 lab results.

Application Recommendations

Common Limestone:

Best for: Long-term, sustained calcium delivery in general agricultural applications. While providing the lowest immediate calcium availability (0.28% solubility, 0.059% water-soluble Ca), this material offers the most stable and predictable release pattern. Suitable for all crop types including salt-sensitive species. Minimal risk of sodium accumulation or salinity issues. Provides highest potassium solubility (65.56%) despite low total content. Ideal for maintenance liming programs where gradual soil improvement is acceptable.

Lake Bonneville Marl:

Best for: Rapid calcium correction in deficient soils and crops with acute calcium needs. Delivers 10.5× more water-soluble calcium than Common Limestone (0.62% vs 0.059%) with 2.95% solubility rate. Exceptional for addressing blossom end rot in tomatoes and peppers, bitter pit in apples, and tip burn in lettuce—all calcium-deficiency disorders requiring immediate correction. Also provides superior magnesium solubility (6.67%, 28× higher than Common Limestone), excellent sulfur availability (55.56% solubility), and outstanding boron content. However, high sodium content (3.75% total, 2.98% soluble with 79.5% solubility) and elevated salinity (EC 26.2) require careful management. Use only in sodium-tolerant crops, well-drained soils with adequate leaching, and with regular soil monitoring. Not suitable for salt-sensitive crops, sodic soils, or areas with poor drainage. A blend plan can also help mitigate the high salinity.

Dolomitized Lake Bonneville Marl:

Best for: Balanced calcium-magnesium delivery with exceptional micronutrient supplementation. Provides 6.8× more water-soluble calcium than Common Limestone (0.20% vs 0.059%) with 1.90% solubility, while delivering the highest magnesium content (2.47% total). Uniquely valuable for iron-deficient soils, offering extraordinary iron reserves (13,134 ppm total) with practical solubility delivering 69 ppm water-soluble Fe—3× more than Common Limestone. Outstanding manganese content (441 ppm total, 2.0 ppm soluble) makes this material ideal for crops sensitive to Mn deficiency. Excellent boron source (20 ppm total, 6 ppm soluble—17× more than Common Limestone). Significantly reduced sodium concerns compared to non-dolomitized Lake Bonneville Marl (0.67% total vs 3.75%), though still elevated compared to Common Limestone. Best choice when combined calcium-magnesium correction is needed along with iron, manganese, and boron supplementation. Particularly valuable for chlorotic crops on high-pH soils where iron availability is naturally limited.

Conclusions

This comparative analysis reveals distinct calcium and nutrient delivery profiles for each material:

1. Calcium delivery varies dramatically among materials: Lake Bonneville Marl provides 10.5× more water-soluble calcium than Common Limestone despite nearly identical total calcium content (~21%). This represents a fundamental difference in calcium availability—0.62% soluble Ca versus 0.059%. The Dolomitized material, with half the total calcium (10.54%), still delivers 3.4× more water-soluble calcium than Common Limestone through enhanced solubility (1.90%). For applications requiring immediate calcium availability, Lake Bonneville materials offer clear advantages over traditional limestone.

2. Secondary macronutrients and micronutrients complement calcium delivery: Lake Bonneville Marl excels in magnesium solubility (6.67%, 28× higher than Common Limestone), making it valuable for combined Ca-Mg correction. The Dolomitized material uniquely provides both substantial calcium (0.20% soluble) and exceptional iron (69 ppm soluble from 13,134 ppm total) plus manganese (2.0 ppm soluble from 441 ppm total), addressing multiple nutritional deficiencies simultaneously.

3. Anomalously high sodium content in the Lake Bonneville marl highlights the need for periodic testing of the material: Lake Bonneville Marl's superior calcium and nutrient delivery comes at the cost of high sodium (3.75% total, 79.5% solubility) and elevated salinity (EC 26.2). Results like this, though not typical, restrict its use to sodium-tolerant crops and well-managed systems. Dolomitization significantly mitigates this concern (0.67% total Na) while maintaining enhanced calcium solubility, making it more broadly applicable than the non-dolomitized material.

4. Material selection must balance immediate availability against long-term sustainability: Common Limestone provides safe, predictable, slow-release nutrition suitable for general applications and all crop types. Lake Bonneville Marl offers rapid correction of acute deficiencies but requires intensive management and is suitable only for specific applications. Dolomitized Lake Bonneville Marl provides the best compromise—significantly enhanced calcium delivery compared to Common

Limestone, exceptional micronutrient supplementation, and manageable (though still elevated) sodium levels. The choice depends on whether immediate calcium availability or long-term sustained release is the priority, and whether sodium management is feasible.

Technical Notes

Analysis Methods: All testing conducted by Stukenholtz Laboratory Inc., Twin Falls, Idaho, using standardized protocols for compost analysis and water-soluble nutrient extraction. Water-soluble testing involved crushing materials to uniform particle size, suspension in deionized water, standardized agitation period, equilibration, filtration, and analysis of dissolved nutrients.

Report Dates: Water-soluble tests dated December 31, 2025. Compost analyses dated January 8, 2026.

Limitations: Water-soluble testing represents a single extraction point and may not fully represent nutrient behavior in actual soil conditions with varying pH, organic matter, microbial activity, and competing ion interactions. Field trials are recommended to validate performance under specific site conditions. These results are for one sampled location of each type. A more comprehensive study with samples taken from locations throughout the basin will help fully establish trends.

Recommendations for Further Testing: Conduct sequential extraction studies to understand time-release characteristics. Perform greenhouse trials comparing plant uptake efficiency. Test materials in representative soil types from intended application areas. Monitor long-term effects on soil structure and chemistry, particularly sodium accumulation patterns.

Also, it will be highly beneficial to add some more data points to this dataset. The single point for each type of material can create some anomalies, as is apparent with the high sodium content in the marl sample analyzed for this study that is not reflected in the compost analysis we have done for similar Marls throughout the basin.

Laboratory testing was conducted by Stukenholtz Laboratory Inc. using standardized protocols for compost analysis and water-soluble nutrient extraction. Comparative solubility analysis, nutrient delivery calculations, and interpretation were drafted using Claude 4.5 Sonnet (Anthropic, 2026), an AI language model, under the direction of the principal investigator, Eric Beard, P.G. All calculations and interpretations were verified against source laboratory reports.

References

Laboratory Reports:

1. Stukenholtz Laboratory Inc. (2025). Water Soluble Test Results: Common Limestone. Report #161435. Dated December 31, 2025. Twin Falls, Idaho.

2. Stukenholtz Laboratory Inc. (2025). Water Soluble Test Results: Lake Bonneville Marl. Report #161436. Dated December 31, 2025. Twin Falls, Idaho.

3. Stukenholtz Laboratory Inc. (2025). Water Soluble Test Results: Dolomitized Lake Bonneville Marl. Report #161437. Dated December 31, 2025. Twin Falls, Idaho.

4. Stukenholtz Laboratory Inc. (2026). Compost Analysis: Common Limestone (Sample I.D.: COMMON LMSTN). Report #5321. Date Received: December 30, 2025. Date Reported: January 8, 2026. Twin Falls, Idaho.

5. Stukenholtz Laboratory Inc. (2026). Compost Analysis: Lake Bonneville Marl (Sample I.D.: LAKE BONNE MARL). Report #5320. Date Received: December 30, 2025. Date Reported: January 8, 2026. Twin Falls, Idaho.

6. Stukenholtz Laboratory Inc. (2026). Compost Analysis: Dolomitized Lake Bonneville Marl (Sample I.D.: DOL LAKE BONN). Report #5319. Date Received: December 30, 2025. Date Reported: January 8, 2026. Twin Falls, Idaho.