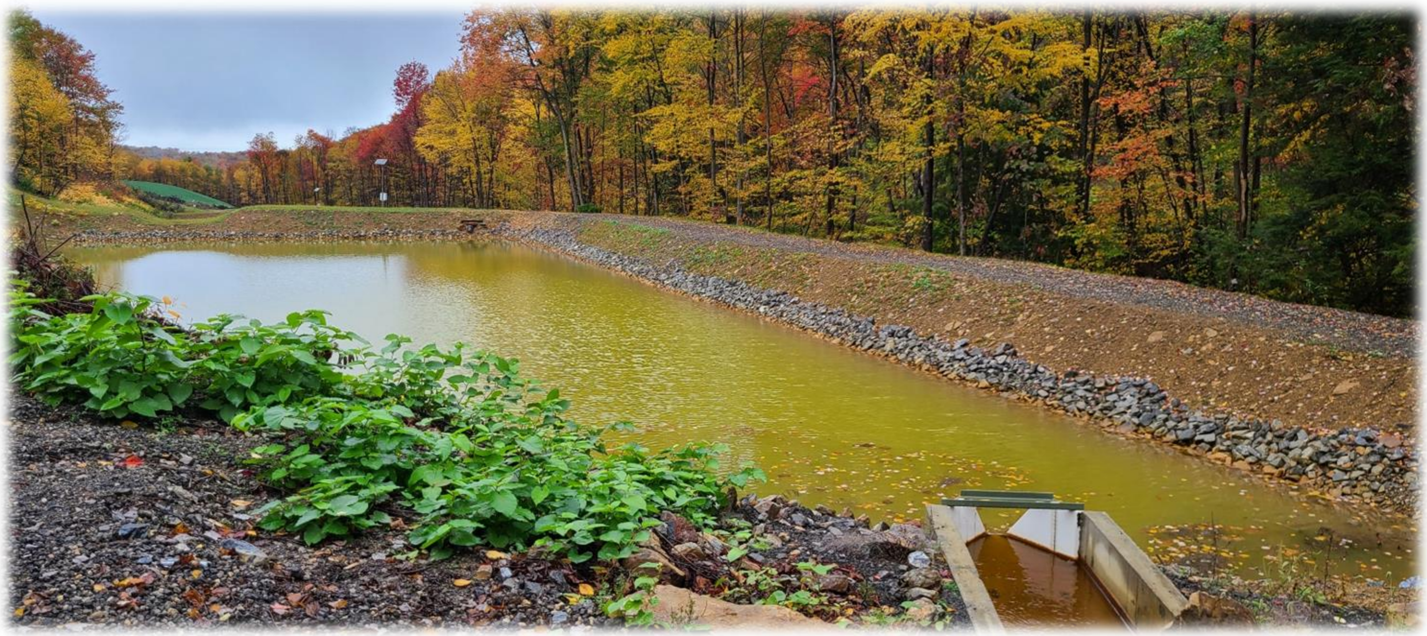
Puritan AMD Full Treatment

Portage Township, Cambria County, Pennsylvania
40.367210, -78.646598

A Trout Run Watershed Association Project

Final Report



October 2020

Project Sponsor:

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Puritan AMD Full Treatment
Final Report

Project Narrative

a. What was the project supposed to accomplish?
The goal of the Puritan AMD Full Treatment Project was the installation of a new passive treatment system capable of treating the entire flow of the TR4 (Puritan) discharge and restore the water quality of Trout Run to meet the designated use as a Cold Water Fishery (PA Code Title 25, Chapter 93). The conceptual plan proposed a system that included two Automatic Flushing Vertical Flow Ponds (AFVFPs) containing a total of 6,500 tons of limestone, two settling ponds and a polishing wetland.

Deliverables from Original Scope of Work (Attachment D)
Deliverable #1: Design and Permitting (grant funded with cash and in-kind match)
Deliverable #2: Construct Passive Treatment System (grant funded with cash match)
Deliverable #3: Construction Oversight, As-Builts, and OM&R Plan (grant funded with in-kind match)
Deliverable #4: Operation and Maintenance (cash and in-kind match)

b. What you actually did and how it differs from your plan?
The as-built passive treatment system is similar to what was initially proposed in that it consists of five pond-type components and utilizes a total of about 6,500 tons of limestone to adjust pH, neutralize acidity, and precipitate iron and aluminum. However, the final treatment system differs from the conceptual plan in that instead of using two stand-alone AFVFPs operating in series, with each AFVFP followed by a settling pond, and a final polishing wetland at the downstream end of the treatment system, the design was enhanced to include a novel flushing system and the pond sequence was reconfigured.

Raw AMD enters a Holding Pond (HP) that upon reaching a certain level as indicated by a float switch drains into the first AFVFP (AFVFP1) that contains about 4,600 tons of limestone. A float switch set at the top of the limestone in AFVFP1 stops the flow from the HP and starts a timer. After a set period, initially 12 hours, AFVFP1 drains to Settling Pond 1 (SP1). A float switch located near the bottom of AFVFP1 sends a signal to shut the AVFP1 valve once the limestone is drained and the cycle starts over again. This is the first known full-scale application of this type of automatic flushing system. SP1 includes a windowed baffle curtain and a floating skimmer-type primary outlet that drains through a pipeline to SP2. There is a valve on the SP1 outlet pipe that can be shut thus directing the flow to AFVFP2 allowing the AFVFPs to function in series.

During high flow periods when the high-water level in the HP is reached between drainage events to AFVFP1, water overflows via pipe to a second AFVFP (AFVFP2) that contains about 2,000 tons of limestone. AFVFP2 operates independently of and in parallel with AFVFP1. The system includes valves and water control features that allow the AFVFPs to function in either parallel (normal) or in series if desired by shutting the SP1 outlet pipe valve. Operational flexibility includes the ability to bypass AFVFP1, AFVFP2, SP2, or the entire system to allow maintenance to be performed as needed.

Another major aspect is that the project partners, including the Trout Run Watershed Association, Stream Restoration Incorporated, BioMost, Inc., Saint Francis University, Foundation For Pennsylvania Watersheds, and the Pennsylvania Department of Environmental Protection Bureau of Abandoned Mine Reclamation were able to partner with Robindale Energy Services, Inc. to expand the project scope and remove barren coal refuse piles that were actively eroding into Trout Run and degrading aquatic habit. This required expanding the project area, revising the project design and erosion and sedimentation control plan, and additional permitting effort. This work resulted in removing four coal refuse piles that would have otherwise remained and continued to degrade Trout Run that now benefits from improved water quality as a result of the passive treatment system.

c. What were your successes and reasons for your success?

The successes include the development and installation of an innovative water handling system that is projected to increase the treatment capacity of limestone-only AVFPS and thereby reduce the cost to provide treatment to acidic, high-flow, abandoned mine drainage discharges and the installation of a full-scale passive treatment system. An additional success was the removal of four coal refuse piles that were eroding into Trout Run. These successes were made possible through a dedicated team of volunteers and professionals with a clear vision of improving Trout Run and the Little Conemaugh River. The cooperative and supportive efforts of the aforementioned partners who have decades of experience working on mine drainage and mine reclamation projects are responsible for the successful completion of the project. The team also received support from the Cambria County Conservation District in the form of clear guidance and prompt response to the evolving needs of the project.

Completed Deliverables from Scope of Work Revised February 2020 (Attachment D)

Deliverable #1: Design and Permitting completed (grant funded with in-kind provided)

a) Pre-construction water sampling with extensive flow monitoring (2+ years data logger) completed by BioMost, Inc. and St. Francis University
b) Extensive bench-scale (bucket) testing to evaluate and develop an innovative design approach completed by BioMost, Inc. and St. Francis University
c) Unique system design developed by BioMost, Inc. using a holding pond to rapidly dose a flushing limestone pond that has a hold time controlled by float switches and electronic timer
d) Permit acquisition completed by BioMost, Inc.
    a. PNDI – Initial Project area (ID # PNDI-685968, 7/2/19)
        i. USFWS restrictions regarding bat habitat (USFWS Project #2019-1169, 8/12/19)
    b. Chapter 102 PAG-02 (NPDES Permit No. PAC110056, 11/26/19)
        i. Minor Amendment approved 2/6/20 (NPDES Permit No. PAC110056 A-1)
        ii. Minor Amendment approved 3/9/20 (NPDES Permit No. PAC110056 A-2)
        iii. Minor Amendment approved 8/5/20 (NPDES Permit No. PAC110056 A-3)
    c. General Permit (GP041100119-001, undated) (APS ID# 998997, Auth ID #1283182)
    d. PNDI for Expanded upstream coal refuse removal – no conflict) (ID # PNDI-702792, 2/5/20)
    e. General Permit (GP-03-1109-20-001, 2/20/20) for upstream coal refuse removal
    f. Approved E&S Plan for upstream coal refuse removal (Project No. AMD 11(2499)101.1, 2/20/20)

Deliverable #2: Construct Passive Treatment System completed (grant funded with cash & in-kind match provided)

Deliverable #3: Construction Oversight, As-Builts, and OM&R Plan (grant funded with in-kind match)

a) Construction oversight completed March through September 2020
b) As-Builts attached
c) OM&R Plan attached

Deliverable #4: Operation and Maintenance (in-kind match) - St. Francis University will conduct on-going O&M

Deliverable #5: Complete Additional Permitting & Design Work to Remove Coal Refuse (grant funded with in-kind match)

a) Added through Growing Greener Amendment #1 to Grant Number 4100074088, 4/24/20
b) Design and permitting effort detailed under Deliverable #1, Permit Acquisition above

Deliverable #6: Remove Coal Refuse Piles from Site and Complete Revegetation (grant funded with in-kind match)

a) Added through Growing Greener Amendment #1 to Grant Number 4100074088, 4/24/20
b) Design and permitting effort detailed under Deliverable #1, Permit Acquisition above
c) Refuse removed by Robindale Energy Services, Inc. and affected areas successfully revegetated

d. What problems were encountered and how you dealt with them?

Overall, the project proceeded as intended with expanded efforts as noted above. The extensive bench-scale tests conducted by Saint Francis University in cooperation with BioMost, Inc. led to the development of an innovative flushing system that required significant additional development effort to design, construct, and install. During design development it was discovered that more limestone than expected was available within the previous treatment system which allowed the project team to afford to install the more extensive flushing system and additional piping systems.

e. How your work contributed to solution of original problems?
Based on initial monitoring data, the installation of the Puritan AMD Full Treatment passive system is providing more-than-sufficient treatment of the TR4 discharge with a documented improvement to Trout Run.

f. What else needs to be done and what additional efforts are underway or planned?
The proposed scope of work has been successfully completed. The treatment system will need to be monitored with maintenance performed as needed. The Pennsylvania Department of Environmental Protection Bureau of Abandoned Mine Reclamation is in the process of developing the Little Conemaugh (Portage) Treatment Plan that will address the other major mine discharges in the Little Conemaugh Watershed that include Sonman D11 and D12, Sonman 13, Miller Shaft, and the Hughes Borehole. St. Francis University plans to continue to monitor the system in conjunction with the Trout Run Watershed Association and conduct evaluation of the innovative treatment approach.

g. What are your plans for disseminating results of your work?
Monitoring data and project documents (As-Builts, O&M Plan, etc.) will be uploaded to www.datashed.org to allow the project partners and other interested parties to access for viewing and/or download.

Bucket-test and system performance data will be presented at state, regional, and national conferences. Initial bucket test results have already been presented at the American Society of Reclamation Sciences (formerly American Society of Mining and Reclamation) 2019 annual conference:

https://www.asrs.us/Portals/0/Documents/Meetings/2019/Abstracts/9D-300-LaBar.pdf

The project partners including Saint Francis University, BioMost, Inc., and Stream Restoration Incorporated will continue to monitor the passive treatment system in cooperation with the Trout Run Watershed Association and plan to present long-term performance data to help document the success of this project and assist others with addressing similar abandoned mine drainage projects. These partners plan to conduct tests on AFVFP1 to demonstrate the scalability of the bench-scale testing. These results will be presented at the aforementioned conferences.

h. How well did your spending align with your budget request?
The proposed passive system was successfully installed in accordance with the original budget amount. Additional funding was received from the US Office of Surface Mining(OSM) Watershed Cooperative Agreement Program (WCAP) as well as the Foundation for Pennsylvania Watersheds as cash match to facilitate the construction of the innovative treatment system. BioMost contributed in-kind construction services in addition to their planned donation of contractual services. Overall, the cash and in-kind match received were greater than expected. The expanded scope of work that included coal refuse removal was made possible by generous in-kind donations from Robindale Energy Services and a budget revision approved by the Pennsylvania Department of Environmental Projection.

Note: The format of this report follows the Final Report Guidelines (Document #1010-FM-GC0056 Rev. 4/2019) provided by the Pennsylvania Department of Environmental Protection for the "Technical Report" requirements.

Appendix 1
Photographs

Photographs

Top: Coal refuse pile, Trout Run is in the background left. (1/10/2020)

Bottom: The same coal refuse pile after reclamation. The coal was removed by Robindale Energy Services, Inc. (Robindale) and used for electricity production. (9/11/2020)

Top: Approximately 1,000 feet upstream of the Passive Treatment System (PTS) was another coal refuse pile immediately adjacent to Trout Run. (1/20/2020)

Bottom: The same location after Robindale removed the coal refuse and reclaimed the area. (9/11/2020)

Top Left: Puritan discharge inlet to the original PTS, the system inflow was restricted to about 100 gpm. (3/5/2020)

Top Right: Puritan discharge bypass that was prevented from entering the PTS and flowed directly to Trout Run. (3/5/2020)

Bottom: Original PTS that consisted of a FeAlMn bed. (FeAlMn is a combination of the elemental symbols for Iron, Aluminum, and Manganese). (3/5/2020)

Left: Measurement of Trout Run during initial site characterization work. (1/15/2019)

Right: GPS benchmarks were set throughout the site to allow for ready access to a known elevation during construction. (3/23/2020)

Top: Tree removal preceded construction work. (3/23/2020)

Bottom: Installation of diversion ditches up gradient of the PTS prior to earthwork. (4/6/2020)

Top: Settling Pond 2 (SP2) was completed first and was used as a sediment basin per the E&S control plan. (6/22/2020)

Bottom: Coal refuse removal by Robindale. (4/6/2020)

Top Left: Fully excavated Auto Flushing Vertical Flow Pond 2 (AFVFP2) prior to being filled with limestone. (4/29/2020)

Bottom Left: Filling AFVFP2 with approximately 2,000 tons of limestone. (5/12/2020)

Right: Installation of Agri Drain Box #3 at outlet of AFVFP2. (4/6/2020)

Left: Removing stone in former FeAlMn bed to and excavation of Holding Pond (HP). (5/20/2020)

Right: Filling AFVFP1 with approximately 4,600 tons of limestone. (5/27/2020)

Top Left: 6” perforated HDPE underdrain in AFVFP1 prior to being filled with limestone. (5/27/2020)

Top Right: The 6” laterals of the AFVFP1 underdrain attached to the 12” perforated HDPE header pipe using flexible saddle tees. (5/27/2020)

Bottom: Close-up of the 1.25” perforations in the 6” HDPE underdrain laterals. (5/27/2020)

Top Left: Excavation of the HP and removal of existing limestone from FeAlMn Bed. (5/27/2020)

Right: Continued excavation of the HP. (6/3/2020)

Bottom Left: Completed HP shown with riprap armoring along the slopes to limit erosion during flush cycles. (9/11/2020)

Top: Instillation of the Agri Drain Smart Drain System. (6/25/2020)

Bottom: Adjusting stop logs within the Agri Drain box to maintain an appropriate water elevation within AFVFP1. (6/25/2020)

Left: Baffle curtain installed within SP2. (9/10/2020)

Right: Baffle curtains have custom cut windows within the curtain to allow water to pass through without forming preferential flow paths. (9/10/2020)

Top Left: A custom floating skimmer is used to dewater SP1 to help buffer flow rates through the system to allow for better treatment and more stable discharge rates into the Trout Run. (9/10/2020)

Top Right: A bar guard is attached to the HP drain pipe that can be removed by pulling the rope attached to a stake along the HP berm. (9/2/2020)

Bottom: Installation of the float switches in the stilling well within AFVFP1. (9/11/2020)

Top: AFVFP1 flushing into SP1. (6/22/2020)

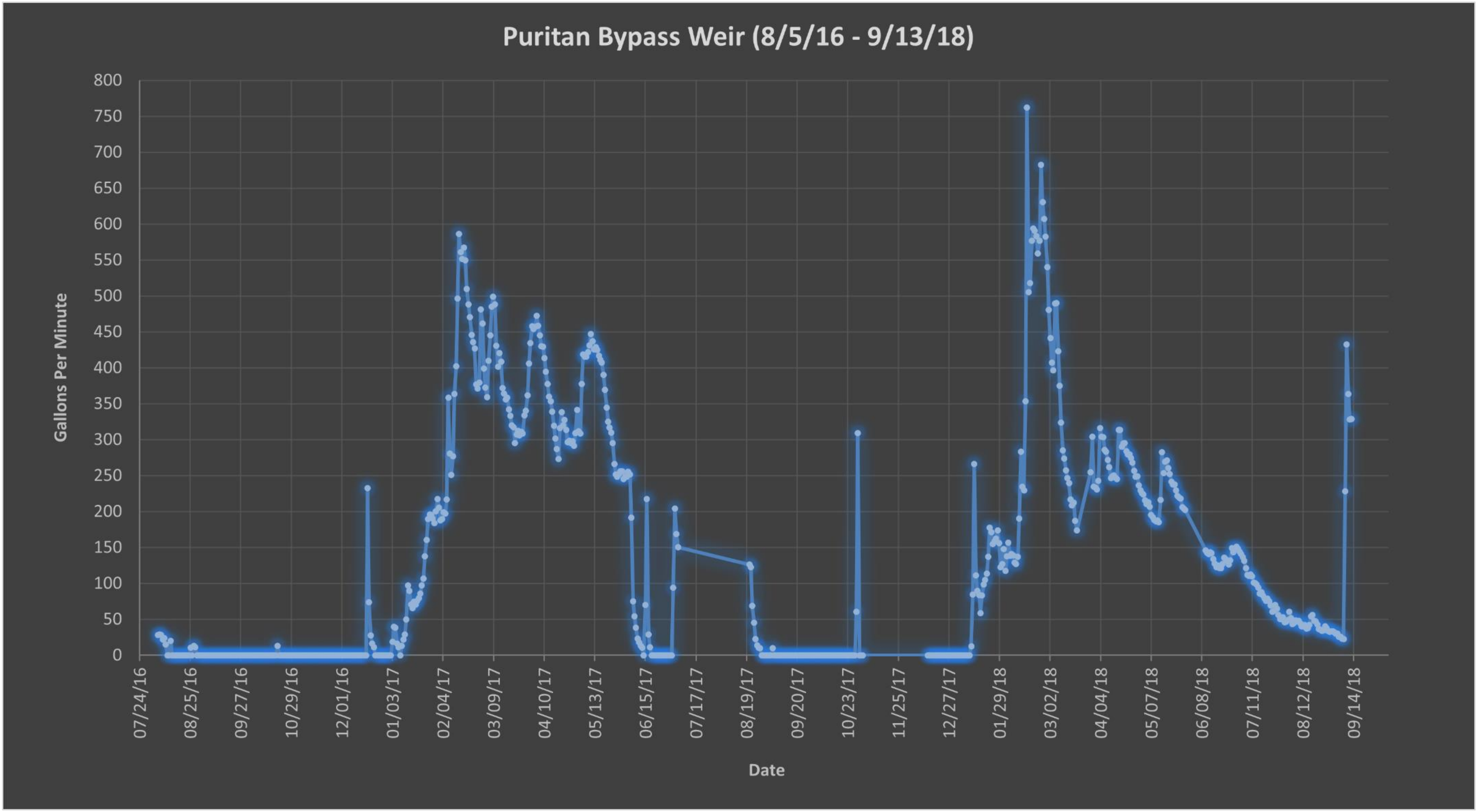
Bottom: Sludge plume seen in SP1 during an AFVFP1 flush event, prior to baffle curtain installation. (6/25/2020)

Left: Installation of a stainless-steel flange adapter to connect the 12" PVC Raw water pipeline to the existing concrete collection box where the Puritan discharge emanates. (6/16/2020)

Right: Trout Run downstream of PTS after the PTS was placed on-line. (9/15/2020)

Appendix 2
Pre-Construction Flow Data

Puritan AMD Full Treatment
Pre-Construction Flow Data



Daily average (flow measured every 15 minutes, n=63,245) flow measured by pressure transducer installed by Saint Francis University at the 2.0-foot rectangular weir in bypass channel along abandoned railroad grade. The weir received flow bypassed from TR4 abandoned mine drainage collection system located at the 24-inch mine drain pipe as well as surface runoff during precipitation events. During monitoring, approximately 100 gpm of mine drainage was directed to the original passive treatment system (i.e. total mine discharge flow is about 100 gpm more than shown on the graph).

Appendix 3
Water Monitoring Data

WATER MONITORING DATA & POLLUTANT LOAD REDUCTION EVALUATION

Combined Raw Discharge (TR4) (Pre-Construction)

Point	Date	Flow	Cond.	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid Load	Fe Load	Mn Load	Al Load
		gpm	umho/cm	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day
Combined RAW	07/06/17	128	1334	3.07	0	138	7.08	5.98	1.36	1.31	13.70	13.30	644	0	212.0	10.9	2.1	21.1
Combined RAW	08/21/17	123	1410	3.04	0	119	11.81	11.81	1.54	1.47	12.80	12.12	829	7	175.3	17.5	2.3	18.9
Combined RAW	09/27/17	115	1437	3.08	0	98	13.90	11.46	1.33	1.27	10.51	9.69	729	10	135.4	19.2	1.8	14.5
Combined RAW	11/02/17	83	1315	3.11	0	77	9.21	8.69	1.07	1.04	7.70	7.44	584	0	76.7	9.2	1.1	7.7
Combined RAW	12/14/17	87	1429	3.07	0	91	7.67	7.64	1.28	1.25	9.26	9.20	628	0	94.8	8.0	1.3	9.7
Combined RAW	02/10/18	175	1467	3.09	0	113	4.89	4.13	1.59	1.56	13.74	13.16	713	0	238.0	10.3	3.3	28.9
Combined RAW	03/21/18	268	1531	2.95	0	142	6.03	5.90	1.65	1.62	14.75	14.59	653	0	459.7	19.5	5.3	47.6
Combined RAW	04/12/18	359	1354	2.88	0	117	3.93	3.88	1.42	1.39	12.14	12.07	715	0	506.2	16.9	6.1	52.4
Combined RAW	05/29/18	325	1320	3.07	0	107	5.35	5.17	1.39	1.35	11.56	11.46	652	0	417.4	20.9	5.4	45.2
Combined RAW	06/27/18	244	1238	3.04	0	105	6.56	6.32	1.25	1.23	10.03	9.79	600	0	309.5	19.3	3.7	29.5
Minimum		**83**	**1238**	**2.88**	**0**	**77**	**3.93**	**3.88**	**1.07**	**1.04**	**7.70**	**7.44**	**584**	**0**	**76.7**	**8.0**	**1.1**	**7.7**
Maximum		**359**	**1531**	**3.11**	**0**	**142**	**13.90**	**11.81**	**1.65**	**1.62**	**14.75**	**14.59**	**829**	**10**	**506.2**	**20.9**	**6.1**	**52.4**
Average		**191**	**1383**	**3.04**	**0**	**111**	**7.64**	**7.10**	**1.39**	**1.35**	**11.62**	**11.28**	**675**	**2**	**262.5**	**15.2**	**3.2**	**27.6**

All zero values indicate values below lab detection limits. Combined RAW consists of the weighted averages of the Bypass (Weir) and Influent sample points
08/21/17 Bypass flow is average of flow measurements taken every 15 minutes for a 24-hour period

Treatment System Components

Point	Date	Flow	Cond.	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid Load	Fe Load	Mn Load	Al Load
		gpm	umho/cm	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day
Combined RAW	09/15/20	97	1222	3.48	0	81	15.71	15.47	1.12	1.10	3.63	3.56	676	0	94.0	18.2	1.3	4.2
HP	09/15/20		1127	3.71	0	67	11.61	11.06	1.17	1.09	3.34	3.09	652	0	78.0	13.5	1.4	3.9
AFVFP1*	09/15/20		1252	7.49	99	-92	1.27	0.22	0.47	0.43	0.64	0.00	670	0	-106.4	1.5	0.5	0.7
SP1	09/15/20		1278	7.87	107	-84	0.42	0.16	0.50	0.48	0.17	0.00	702	0	-97.9	0.5	0.6	0.2
AFVFP2**	09/15/20	0																
SP2	09/15/20	97	1269	8.05	106	-100	0.37	0.16	0.59	0.56	0.21	0.00	680	0	-116.4	0.4	0.7	0.2
														Load Reduction (RAW - SP2):	**210.4**	**17.8**	**0.6**	**4.0**

*AFVFP1 sample was taken 20 minutes after initiation of a flush cycle. ** AFVFP2 will only receive water when RAW water flow rates exceed approximately 400 GPM.
Post-construction RAW is entire TR4 discharge. SP2 flow assumed to be same as RAW due to flushing creating dynamic flow conditions.

Stream Samples Above and Below AMD Treatment System

Point	Date	Flow	Cond.	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid Load	Fe Load	Mn Load	Al Load
		gpm	umho/cm	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day
Up-Stream	09/27/17	150	380	7.13	34	-30	0.26	0.00	0.13	0.00	0.22	0.00	112	11	-35.0	0.3	0.2	0.3
Up-Stream	05/29/18	2203	179	6.94	13	-7	0.74	0.00	0.57	0.53	1.04	0.00	43	23	-8.5	0.9	0.7	1.2
Up-Stream	06/27/18	1993	204	6.71	11	-5	0.43	0.00	0.67	0.59	1.06	0.00	49	15	-5.8	0.5	0.8	1.2
Up-Stream	**Average**	**1449**	**254**	**6.93**	**19**	**-14**	**0.48**	**0.00**	**0.46**	**0.37**	**0.77**	**0.00**	**68**	**16**	**-16.4**	**0.6**	**0.6**	**0.9**
Up-Stream	**09/15/20**	N.M.	**374**	**7.65**	**39**	**-34**	**0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**108**	**0**	**-39.1**	**0.1**	**0.0**	**0.0**
Down-Stream	09/27/17	264	858	6.96	34	-28	1.05	0.00	0.30	0.21	1.63	0.12	392	8	-32.9	1.2	0.3	1.9
Down-Stream	05/29/18	2640	280	6.83	12	-1	1.30	1.06	0.59	0.59	1.91	1.69	87	35	-0.9	1.5	0.7	2.2
Down-Stream	06/27/18	2244	369	5.32	1	4	0.96	0.00	0.70	0.67	2.36	0.22	138	17	5.1	1.1	0.8	2.7
Down-Stream	**Average**	**1716**	**502**	**6.37**	**16**	**-8**	**1.10**	**0.35**	**0.53**	**0.49**	**1.97**	**0.68**	**206**	**20**	**-9.6**	**1.3**	**0.6**	**2.3**
Down-Stream	**09/15/20**	N.M.	**786**	**7.80**	**54**	**-47**	**0.87**	**0.18**	**0.19**	**0.19**	**0.00**	**0.00**	**509**	**0**	**-54.1**	**1.0**	**0.2**	**0.0**

Red shading indicates pre-construction average | Blue shading indicates post-construction sample | Yellow shading indicates new treatment component sample

All zero values indicate values below lab detection limits. See as-built plan for Point locations.

WATER MONITORING DATA

Pre-Construction Monitoring

Point	Date	Flow	Cond.	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid Load	Fe Load	Mn Load	Al Load
		gpm	umho/cm	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day
Bypass (Weir)	07/06/17	150	1321	3.07	ND	150	7.77	5.88	1.36	1.31	13.72	13.24	659	<5	270.3	14.0	2.5	24.7
Influent	07/06/17	128	1350	3.08	ND	124	6.28	6.09	1.36	1.31	13.68	13.38	626	<5	190.2	9.7	2.1	21.0
Effluent	07/06/17	133	1227	6.56	52	-42	0.63	0.12	0.73	0.72	3.94	0.14	599	15	-67.5	1.0	1.2	6.3
Bypass (Weir)	08/21/17	126	1373	3.04	ND	107	8.44	8.31	1.46	1.45	12.62	12.20	673	5				
Influent	08/21/17	123	1410	3.04	ND	119	11.81	11.32	1.54	1.47	12.80	12.12	829	7	175.3	17.5	2.3	18.9
Effluent	08/21/17	119	1280	6.35	35	-22	1.75	0.24	0.87	0.84	4.46	0.27	648	20	-31.8	2.5	1.2	6.4
Influent	09/27/17	115	1437	3.08	<0.10	98	13.90	11.46	1.33	1.27	10.51	9.69	729	10	135.4	19.2	1.8	14.5
Effluent	09/27/17	113	1345	6.39	40	-31	2.93	0.59	0.69	0.60	4.20	<0.10	691	17	-42.1	4.0	0.9	5.7
Bypass (Weir)	11/02/17	0																
Influent	11/02/17	83	1315	3.11	ND	77	9.21	8.69	1.07	1.04	7.70	7.44	584	<5	76.7	9.2	1.1	7.7
Effluent	11/02/17	68	1213	6.65	31	-26	0.90	0.24	0.52	0.52	1.71	<0.10	589	7	-21.3	0.7	0.4	1.4
Bypass (Weir)	12/14/17	0																
Influent	12/14/17	87	1429	3.07	ND	91	7.67	7.64	1.28	1.25	9.26	9.20	628	<5	94.8	8.0	1.3	9.7
Effluent	12/14/17	74	1239	5.77	4	1	1.24	0.30	0.73	0.72	3.64	0.80	628	13	1.2	1.1	0.6	3.2
Bypass (Weir)	02/10/18	64	1438	3.12	ND	112	3.94	3.83	1.59	1.57	13.61	13.00	709	<5	86.0	3.0	1.2	10.5
Influent	02/10/18	130	1481	3.07	ND	114	5.36	4.28	1.59	1.55	13.81	13.24	715	<5	177.2	8.3	2.5	21.5
Effluent	02/10/18	120	1250	4.22	ND	31	1.01	0.46	1.12	1.10	6.79	5.67	689	9	44.2	1.5	1.6	9.8
Bypass (Weir)	03/21/18	174	1526	2.95	ND	142	5.88	5.80	1.63	1.60	14.63	14.53	655	<5	296.3	12.3	3.4	30.6
Influent	03/21/18	94	1539	2.94	ND	144	6.32	6.09	1.68	1.66	14.97	14.71	649	<5	163.4	7.2	1.9	17.0
Effluent	03/21/18	101	1286	4.26	ND	46	2.44	0.68	1.25	1.21	10.00	9.44	674	7	56.5	3.0	1.5	12.2
Bypass (Weir)	04/12/18	253	1335	2.90	ND	113	3.88	3.85	1.42	1.39	12.10	12.06	683	<5	343.6	11.8	4.3	36.8
Influent	04/12/18	106	1398	2.83	ND	128	4.04	3.96	1.42	1.39	12.25	12.10	793	5	162.5	5.1	1.8	15.6
Effluent	04/12/18	121	1167	4.38	ND	14	0.94	0.50	0.96	0.94	4.81	2.69	590	15	20.8	1.4	1.4	7.0
Bypass (Weir)	05/29/18	193	1317	3.07	ND	106	5.26	5.17	1.39	1.34	11.48	11.47	669	<5	245.6	12.2	3.2	26.6
Influent	05/29/18	132	1324	3.06	ND	108	5.49	5.17	1.39	1.37	11.67	11.44	626	<5	171.8	8.7	2.2	18.6
Effluent	05/29/18	113	1209	5.93	22	-11	1.38	0.34	0.80	0.79	5.08	0.14	624	24	-15.4	1.9	1.1	6.9
Bypass (Weir)	06/27/18	130	1242	3.04	ND	105	6.21	6.20	1.23	1.22	9.93	9.58	589	<5	164.7	9.7	1.9	15.5
Influent	06/27/18	114	1233	3.03	ND	105	6.96	6.46	1.27	1.24	10.15	10.04	611	<5	144.8	9.6	1.7	13.9
Effluent	06/27/18	118	1162	6.59	62	-50	1.66	1.41	0.73	0.72	3.02	2.41	579	18	-70.9	2.4	1.0	4.3

Bypass (Weir) collected at 2.0-foot rectangular weir; Influent collected at pipe discharging to previous limestone bed; Effluent collected at previous limestone bed outlet pipe.

Appendix 4
Bench-Scale (Bucket) Test Results

Bucket 1A Start Date: 5/21/2018 End Date: 5/21/2018

Method Add All Water at Once - Field Test every 15 Mins for the first 2 HRS, then every HR up to 12 HRS

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null

Puritan Bench-Scale "Bucket" Test

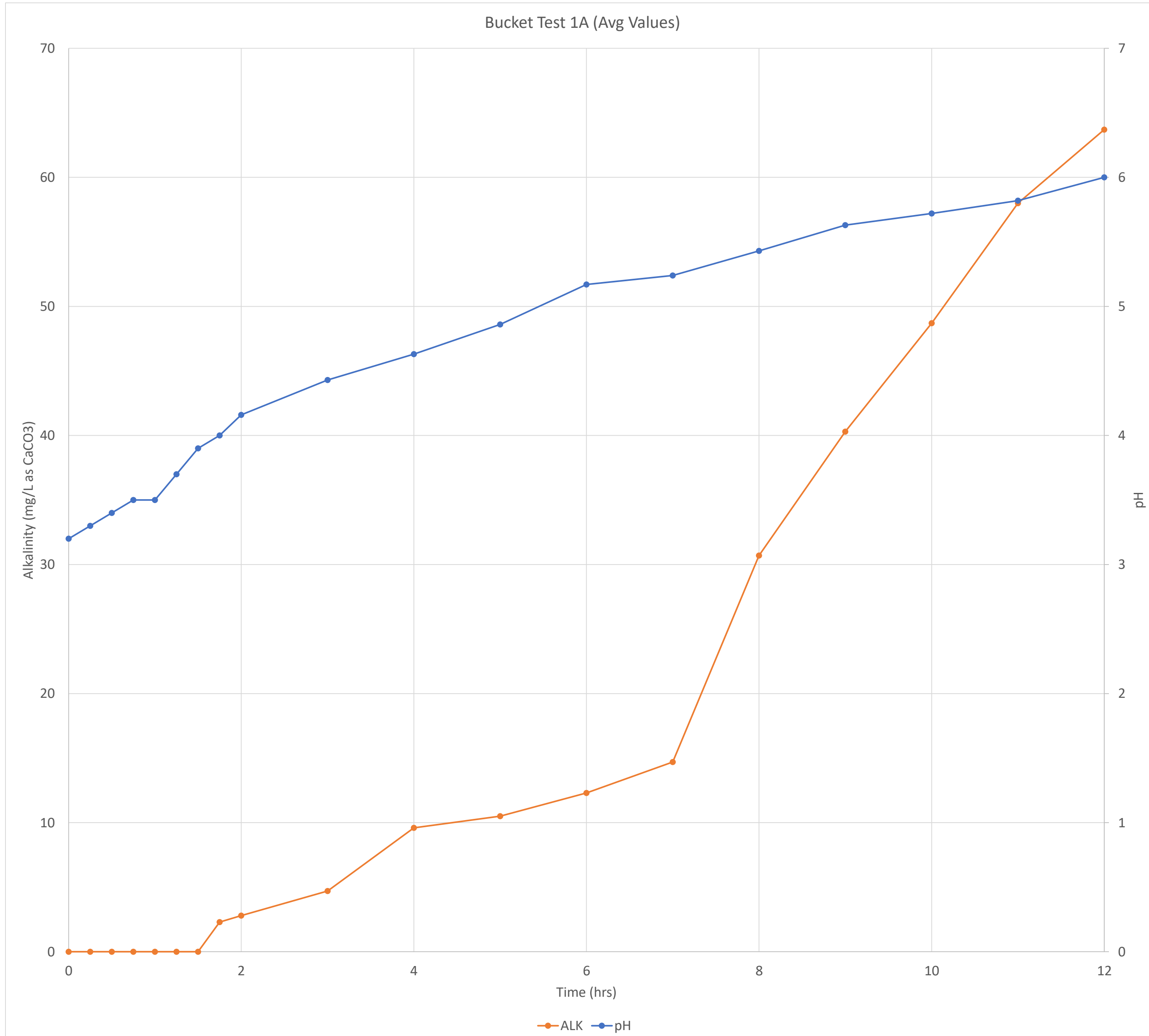
Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

Bucket Data - Conducted by SFU

		Temp (C)	D.O. (%)	DO (mg/L)	SPC (µS/cm)	pH (field)	Alkalinity
Raw	Bucket 1A-1	13.8	63	6.44	1138	3.25	0
	Bucket 1A-2	12.8	57.6	6.05	1172	3.13	0
	Bucket 1A-3	13.2	58.1	6.05	1166	3.11	0
	Average	**13.3**	**59.6**	**6.18**	**1159**	**3.16**	**0**
15 Min	Bucket 1A-1	14.7	64	6.44	1087	3.34	0
	Bucket 1A-2	14.5	66.3	6.7	1112	3.25	0
	Bucket 1A-3	14.3	71.3	7.16	1082	3.30	0
	Average	**14.5**	**67.2**	**6.8**	**1094**	**3.30**	**0**
30 Min	Bucket 1A-1	14.9	68.5	7.04	1072	3.49	0
	Bucket 1A-2	14.6	67.5	6.9	1093	3.36	0
	Bucket 1A-3	14.6	64.3	6.53	1093	3.35	0
	Average	**14.7**	**66.8**	**6.8**	**1086**	**3.40**	**0**
45 Min	Bucket 1A-1	15	69.5	7.1	1057	3.52	0
	Bucket 1A-2	14.7	66.3	6.8	1078	3.43	0
	Bucket 1A-3	14.7	58.1	5.88	1080	3.42	0
	Average	**14.8**	**64.6**	**6.6**	**1072**	**3.46**	**0**
60 Min	Bucket 1A-1	15.1	59.8	5.93	1045	3.65	0
	Bucket 1A-2	14.8	60.2	6.1	1062	3.53	0
	Bucket 1A-3	14.8	55.2	5.56	1071	3.46	0
	Average	**14.9**	**58.4**	**5.9**	**1059**	**3.55**	**0**
75 Min	Bucket 1A-1	15.2	60	6	1034	3.81	0
	Bucket 1A-2	14.9	57.4	5.8	1053	3.63	0
	Bucket 1A-3	14.8	58.2	5.86	1056	3.58	0
	Average	**15.0**	**58.5**	**5.9**	**1048**	**3.67**	**0**
90 Min	Bucket 1A-1	15.3	61	6.09	1025	4.02	0
	Bucket 1A-2	15	59.8	6.04	1029	3.99	0
	Bucket 1A-3	15	56	5.62	1051	3.64	0
	Average	**15.1**	**58.9**	**5.9**	**1035**	**3.88**	**0**
105 Min	Bucket 1A-1	15.5	59.2	5.85	1023	4.22	4
	Bucket 1A-2	15.2	60.2	6.03	1028	4.04	3
	Bucket 1A-3	15.1	52	5.21	1043	3.71	0
	Average	**15.3**	**57.1**	**5.7**	**1031**	**3.99**	**2**
120 Min	Bucket 1A-1	15.6	58.2	5.8	1024	4.43	5.2
	Bucket 1A-2	15.3	59.7	5.97	1025	4.26	3.2
	Bucket 1A-3	15.2	52.4	5.25	1038	3.8	0
	Average	**15.4**	**56.8**	**5.7**	**1029**	**4.16**	**2.8**
3 hr	Bucket 1A-1	15.8	65.3	6.55	1028	4.6	6.4
	Bucket 1A-2	15.5	64.5	6.44	1029	4.54	6
	Bucket 1A-3	15.5	64.3	6.42	1018	4.15	1.6
	Average	**15.6**	**64.7**	**6.5**	**1025**	**4.43**	**4.7**
4 hr	Bucket 1A-1	15.9	57.7	5.73	1036	4.82	11.2
	Bucket 1A-2	15.8	58.7	5.81	1033	4.65	9.6
	Bucket 1A-3	15.7	67.3	6.68	1026	4.42	8
	Average	**15.8**	**61.2**	**6.1**	**1032**	**4.63**	**9.6**
5 hr	Bucket 1A-1	16	59	5.82	1046	5.08	12.8
	Bucket 1A-2	15.9	62.4	6.18	1040	4.85	10
	Bucket 1A-3	15.9	66.9	6.62	1031	4.65	8.8
	Average	**15.9**	**62.8**	**6.2**	**1039**	**4.86**	**10.5**
6 hr	Bucket 1A-1	16.2	61.9	6.07	1057	5.29	14.4
	Bucket 1A-2	16.1	62.2	6.14	1047	5.04	12.8
	Bucket 1A-3	16	69.4	6.85	1037	4.8`	9.6
	Average	**16.1**	**64.5**	**6.4**	**1047**	**5.17**	**12.3**
7 hr	Bucket 1A-1	16.2	64.3	6.25	1074	5.49	19.6
	Bucket 1A-2	16.3	66.4	6.48	1063	5.29	14.8
	Bucket 1A-3	16.2	68.7	6.73	1040	4.94	9.6
	Average	**16.2**	**66.5**	**6.5**	**1059**	**5.24**	**14.7**
8 hr	Bucket 1A-1	16.3	60.1	5.86	1095	5.69	41
	Bucket 1A-2	16.3	62.3	6.07	1075	5.47	33
	Bucket 1A-3	16.3	69.6	6.79	1043	5.12	18
	Average	**16.3**	**64.0**	**6.2**	**1071**	**5.43**	**31**
9 hr	Bucket 1A-1	16.4	63.8	6.2	1109	5.81	53
	Bucket 1A-2	16.5	63.5	6.17	1095	5.66	44
	Bucket 1A-3	16.4	68.4	6.64	1064	5.43	24
	Average	**16.4**	**65.2**	**6.3**	**1089**	**5.63**	**40**
10 hr	Bucket 1A-1	16.5	62.8	6.1	1123	5.9	66
	Bucket 1A-2	16.6	64.6	6.28	1104	5.73	50
	Bucket 1A-3	16.4	69.6	6.78	1064	5.52	30
	Average	**16.5**	**65.7**	**6.4**	**1097**	**5.72**	**49**
11 hr	Bucket 1A-1	16.6	65.6	6.35	1139	5.98	75
	Bucket 1A-2	16.6	65.4	6.34	1116	5.84	62
	Bucket 1A-3	16.5	70	6.83	1075	5.65	37
	Average	**16.6**	**67.0**	**6.5**	**1110**	**5.82**	**58**
12 hr	Bucket 1A-1	16.8	59.5	5.75	1158	6.19	83
	Bucket 1A-2	16.8	59.2	5.71	1129	6.03	69
	Bucket 1A-3	16.6	58.2	5.65	1090	5.79	39
	Average	**16.7**	**59.0**	**5.70**	**1126**	**6.00**	**64**

Hot Acidity - Conducted by SFU / Lab Analysis - Conducted by G&C Labs

		H2SO4 Added (mL)	NaOH Added (mL)	Acidity (mg/L as CaCO3)	Lab PH	Cond. (umhos)	Acidity (mg/L)	Total Fe (mg/L)	Dis. Fe (mg/L)	Total Mn (mg/L)	Dis. Mn (mg/L)	Total Al (mg/L)	Dis. Al (mg/L)	SO4 (mg/L)	TSS (mg/L)
Raw	Bucket 1A-1	5	27	110	3.09	1271	103.88	5.48	5.34	1.38	1.32	10.24	10.46	633.4	<5
	Bucket 1A-2	0	21.7	108.5	3.09	1287	98.51	5.42	5.17	1.33	1.32	10.16	10.12	621.5	<5
	Bucket 1A-3	0	21.9	109.5	3.09	1281	101.69	5.64	5.47	1.37	1.36	10.02	10.01	585.9	<5
	Average	**2**	**23.5**	**109.3**	**3.09**	**1280**	**101.36**	**5.51**	**5.33**	**1.36**	**1.33**	**10.14**	**10.20**	**613.6**	**<5**
12 hr	Bucket 1A-1	30	12.7	-86.5					<0.10		1.27		0.1		
	Bucket 1A-2	20	7.1	-64.5					<0.10		1.32		0.18		
	Bucket 1A-3	10	3.3	-33.5					<0.10		1.32		0.28		
	Average	**20**	**7.7**	**-61.5**					**<0.10**		**1.30**		**0.19**		



Bucket 1B Start Date: 5/22/2018 End Date: 5/23/2018

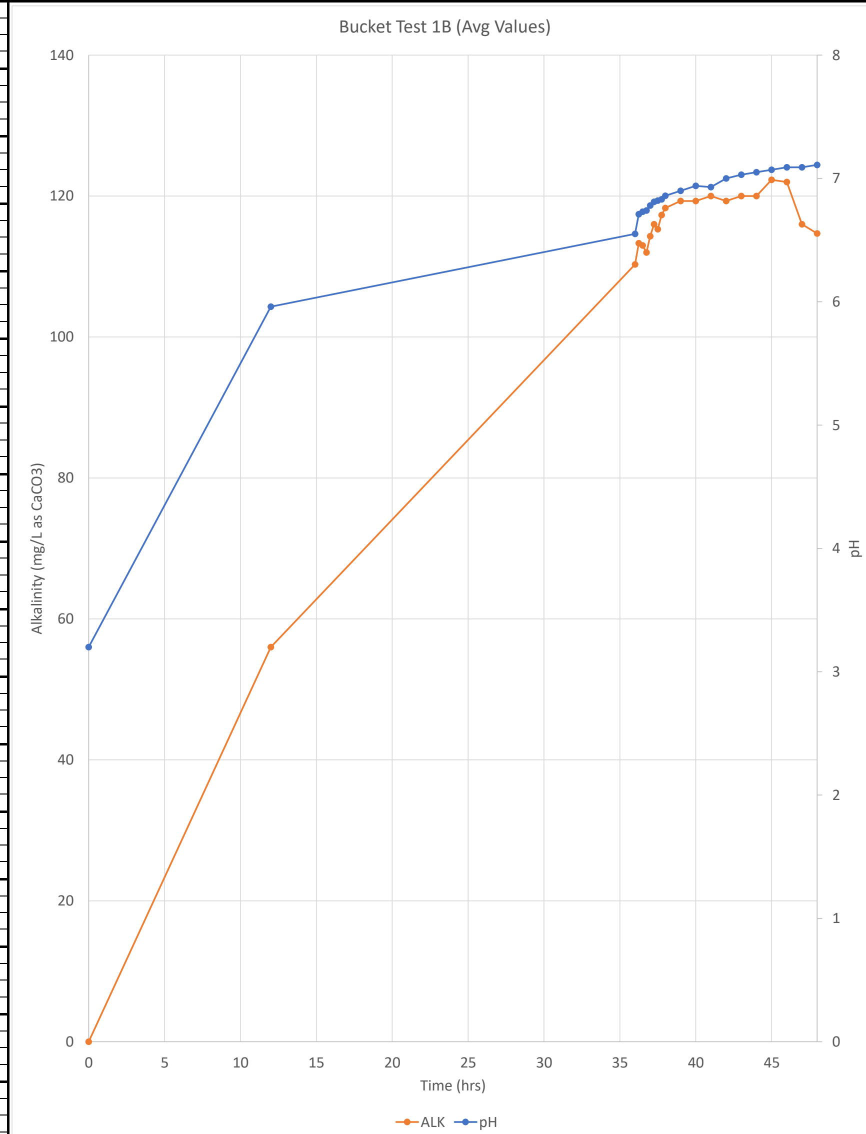
Puritan Bench-Scale "Bucket" Test

Method Add All Water at Once to Bucket - Let Stand for 12 HRS - Drain - Let Stand for 24 HRS - REPEAT BUCKET 1B (Traditional Bucket Test)

Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp (C)	D.O. (%)	DO (mg/L)	SPC (µS/cm)	pH (field)	Alkalinity	H2SO4 Added (mL)	NaOH Added (mL)	Acidity (mg/L as CaCO3)	Lab PH	Cond. (umhos)	Acidity (mg/L)	Total Fe (mg/L)	Dis. Fe (mg/L)	Total Mn (mg/L)	Dis. Mn (mg/L)	Total Al (mg/L)	Dis. Al (mg/L)	SO4 (mg/L)	TSS (mg/L)
Raw	Bucket 1B-1	14.2	47.1	4.81	1160	3.28	0	5	26.6	108.0	3.09	1289	104.08	5.32	5.14	1.37	1.35	10.65	10.43	585.9	<5
	Bucket 1B-2	14	43.1	4.43	1181	3.17	0	0	22.4	112.0	3.06	1294	100.89	5.39	5.14	1.35	1.34	10.59	10.03	615.6	<5
	Bucket 1B-3	14.2	42.6	4.35	1183	3.15	0	0	21.7	108.5	3.09	1290	101.29	5.43	5.11	1.37	1.34	10.59	10.48	574	<5
	Average	**14.1**	**44.3**	**4.53**	**1175**	**3.20**	**0**	**2**	**23.6**	**109.5**	**3.08**	**1291**	**102.087**	**5.38**	**5.13**	**1.36**	**1.34**	**10.61**	**10.31**	**591.8**	**<5**
15 Min	Bucket 1B-1	17.6	66.5	6.32	1210	6.71	112														
	Bucket 1B-2	17.5	64	6.07	1225	6.72	123														
	Bucket 1B-3	17.5	60.3	5.74	1202	6.7	105														
	Average	**17.5**	**63.6**	**6.04**	**1212**	**6.71**	**113**														
30 Min	Bucket 1B-1	17.6	60	5.7	1211	6.74	111														
	Bucket 1B-2	17.6	62.1	5.9	1231	6.75	122														
	Bucket 1B-3	17.5	61.1	5.84	1205	6.7	106														
	Average	**17.6**	**61.1**	**5.81**	**1216**	**6.73**	**113**														
45 Min	Bucket 1B-1	17.7	64.8	6.14	1203	6.75	110														
	Bucket 1B-2	17.6	66.4	6.32	1233	6.76	122														
	Bucket 1B-3	17.5	63.3	6.01	1209	6.72	104														
	Average	**17.6**	**64.8**	**6.16**	**1215**	**6.74**	**112**														
60 Min	Bucket 1B-1	17.7	63.4	6.04	1216	6.77	114														
	Bucket 1B-2	17.6	64.4	6.12	1234	6.79	123														
	Bucket 1B-3	17.5	64.5	6.14	1210	6.77	106														
	Average	**17.6**	**64.1**	**6.10**	**1220**	**6.78**	**114**														
75 Min	Bucket 1B-1	17.7	61	5.78	1217	6.82	113														
	Bucket 1B-2	17.6	66.7	6.34	1236	6.82	123														
	Bucket 1B-3	17.6	62.8	5.94	1212	6.8	112														
	Average	**17.6**	**63.5**	**6.02**	**1222**	**6.81**	**116**														
90 Min	Bucket 1B-1	17.8	54.2	5.13	1218	6.83	111														
	Bucket 1B-2	17.6	69.1	6.53	1237	6.84	124														
	Bucket 1B-3	17.6	60.8	5.77	1214	6.8	111														
	Average	**17.7**	**61.4**	**5.81**	**1223**	**6.82**	**115**														
105 Min	Bucket 1B-1	17.8	56.3	5.35	1219	6.84	114														
	Bucket 1B-2	17.6	66.7	6.3	1238	6.85	126														
	Bucket 1B-3	17.6	60.2	5.72	1214	6.8	112														
	Average	**17.7**	**61.1**	**5.79**	**1224**	**6.83**	**117**														
120 Min	Bucket 1B-1	17.8	56.7	5.36	1219	6.86	117														
	Bucket 1B-2	17.6	62.2	5.9	1238	6.87	125														
	Bucket 1B-3	17.6	61.1	5.8	1216	6.85	113														
	Average	**17.7**	**60.0**	**5.69**	**1224**	**6.86**	**118**														
3 hr	Bucket 1B-1	17.7	62.2	5.89	1222	6.91	117														
	Bucket 1B-2	17.6	60.1	5.72	1240	6.93	127														
	Bucket 1B-3	17.4	58.6	5.61	1219	6.87	114														
	Average	**17.6**	**60.3**	**5.74**	**1227**	**6.90**	**119**														
4 hr	Bucket 1B-1	17.6	64.2	6.14	1223	6.95	114														
	Bucket 1B-2	17.4	60.3	5.74	1242	6.96	126														
	Bucket 1B-3	17.3	57.5	5.5	1221	6.91	118														
	Average	**17.4**	**60.7**	**5.79**	**1229**	**6.94**	**119**														
5 hr	Bucket 1B-1	17.4	61.6	5.88	1223	6.93	114														
	Bucket 1B-2	17.3	61.5.	5.87	1242	6.95	128														
	Bucket 1B-3	17.2	59.7	5.72	1224	6.92	118														
	Average	**17.3**	**60.7**	**5.82**	**1230**	**6.93**	**120**														
6 hr	Bucket 1B-1	17.3	59.3	5.67	1226	7.01	115														
	Bucket 1B-2	17.1	60.7	5.82	1244	7.02	126														
	Bucket 1B-3	17.1	57.4	5.52	1226	6.98	117														
	Average	**17.2**	**59.1**	**5.67**	**1232**	**7.00**	**119**														
7 hr	Bucket 1B-1	17.2	59.8	5.73	1228	7.04	114														
	Bucket 1B-2	17.1	61.9	5.95	1244	7.05	128														
	Bucket 1B-3	17	60.5	5.81	1229	7.02	118														
	Average	**17.1**	**60.7**	**5.83**	**1234**	**7.04**	**120**														
8 hr	Bucket 1B-1	17.1	60	5.77	1228	7.05	114														
	Bucket 1B-2	17	58.5	5.61	1245	7.06	128														
	Bucket 1B-3	16.9	58.9	5.68	1230	7.03	118														
	Average	**17.0**	**59.1**	**5.69**	**1234**	**7.05**	**120**														
9 hr	Bucket 1B-1	17	57.6	5.55	1229	7.08	118														
	Bucket 1B-2	17	59.5	5.73	1246	7.09	130														
	Bucket 1B-3	16.9	55.8	5.39	1231	7.05	119														
	Average	**17.0**	**57.6**	**5.56**	**1235**	**7.07**	**122**														
10 hr	Bucket 1B-1	17	59.1	5.7	1230	7.09	118														
	Bucket 1B-2	17	57.2	5.51	1246	7.1	128														
	Bucket 1B-3	16.9	57.5	5.54	1233	7.07	120														
	Average	**17.0**	**57.9**	**5.58**	**1236**	**7.09**	**122**														
11 hr	Bucket 1B-1	17	55.9	5.38	1230	7.1	114														
	Bucket 1B-2	17.1	57.5	5.53	1247	7.11	120														
	Bucket 1B-3	17	60.4	5.81	1234	7.07	114														
	Average	**17.0**	**57.9**	**5.57**	**1237**	**7.09**	**116**														
12 hr	Bucket 1B-1	16.7	58.7	5.68	1157	5.87	83	25	7.3	-88.5					<0.10		1.34		0.23		
	Bucket 1B-2	16.7	49.4	4.78	1169	6.01	59	20	4.9	-75.5					<0.10		1.33		0.19		
	Bucket 1B-3	16.7	51.8	5.02	1124	6.01	26	15	5.2	-49.0					<0.10		1.33		0.29		
	Average	**16.7**	**53.3**	**5.16**	**1150**	**5.96**	**56**	**20**	**5.8**	**-71.0**					**<0.10**		**1.33**		**0.24**		
36 hr	Bucket 1B-1	17.6	60	5.69	1201	6.54	105	30	6.8	-116.0					<0.10		1.36		0.12		
	Bucket 1B-2	17.4	50.9	4.86	1221	6.55	122	30	3.9	-130.5					<0.10		1.37		<0.10		
	Bucket 1B-3	17.4	54.6	5.22	1022	6.57	104	25	3.3	-108.5					<0.10		1.33		0.11		
	Average	**17.5**	**55.2**	**5.26**	**1148**	**6.55**	**110**	**28**	**4.7**	**-118.3**					**<0.10**		**1.35**		**0.12**		
48 hr	Bucket 1B-1	17.1	53	5.09	1231	7.12	114	30	6	-120.0					<0.10		1.18		0.12		
	Bucket 1B-2	17.2	51.6	4.94	1248	7.13	118	30	3.8	-131.0					<0.10		1.12		0.1		
	Bucket 1B-3	17.1	52.9	5.08	1235	7.08	112	30	5.7	-121.5					<0.10		1.24		0.1		
	Average	**17.1**	**52.5**	**5.04**	**1238**	**7.11**	**115**	**30**	**5.2**	**-124.2**					**<0.10**		**1.18**		**0.11**		

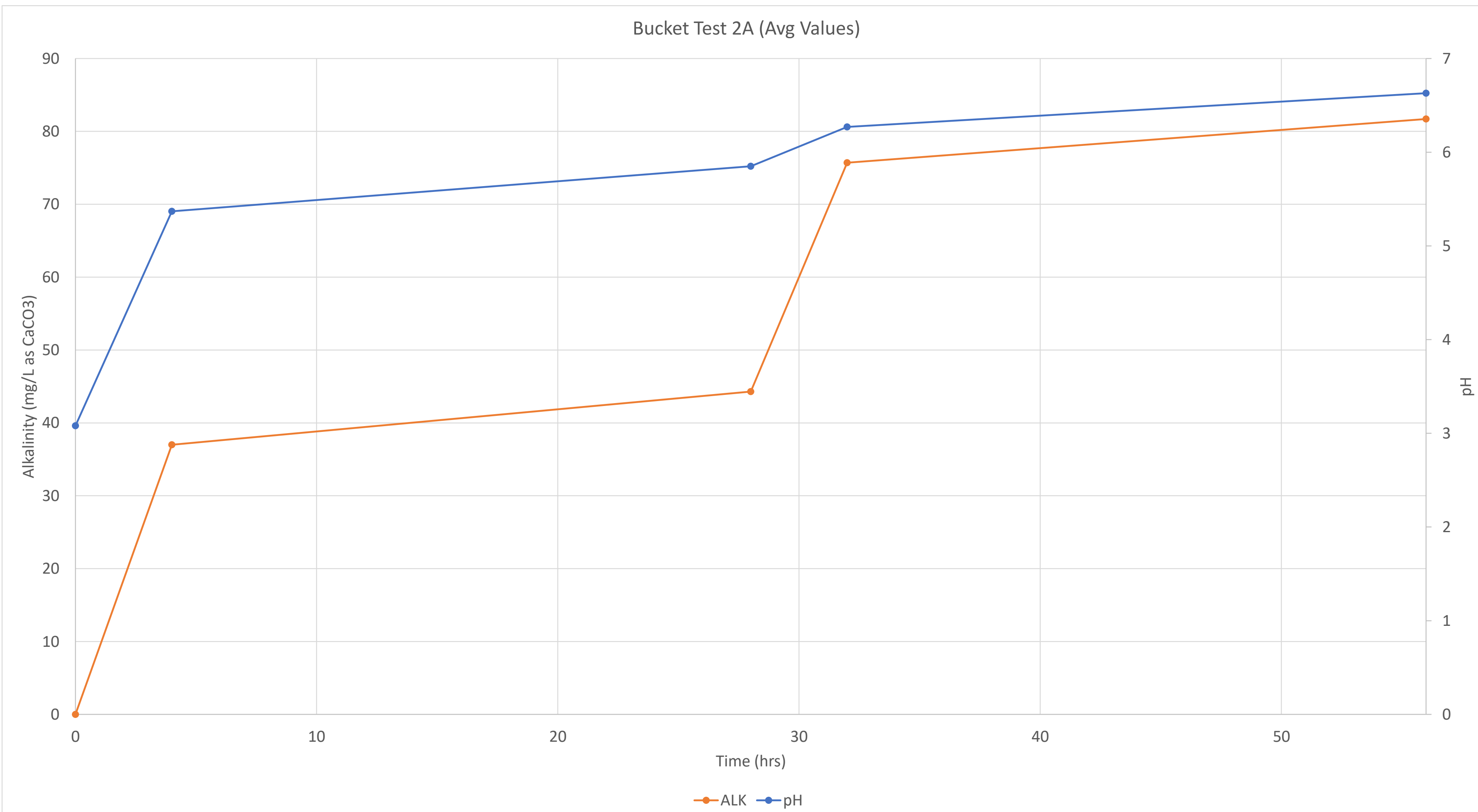


Bucket 2A Start Date: 4/18/2018 End Date: 4/20/2018 **Puritan Bench-Scale "Bucket" Test**

Method Add Water All at Once - Let Stand for 4 HRS - Drain - Let Stand for 24 HRS- REPEAT Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp (C)	D.O. (%)	DO (mg/L)	SPC (µS/cm)	pH (field)	Alkalinity	H2SO4 Added (mL)	NaOH Added (mL)	Acidity (mg/L as CaCO3)	Lab PH	Cond. (umhos)	Acidity (mg/L)	Total Fe (mg/L)	Dis. Fe (mg/L)	Total Mn (mg/L)	Dis. Mn (mg/L)	Total Al (mg/L)	Dis. Al (mg/L)	SO4 (mg/L)	TSS (mg/L)
Raw		10.30	73.30	6.18	1119	3.08		0.0	22.2	111.0	3.00	1220	105.87	--	4.59	--	1.34	--	10.43	532.30	12
4 Hr	Bucket 2A-1	15.9	45.7	4.50	1139	5.33	39	10	5.2	-24.0					<0.10		1.05		<0.10		
	Bucket 2A-2	15.7	47.0	4.65	1130	5.37	38	10	6.0	-20.0					<0.10		1.15		<0.10		
	Bucket 2A-3	15.9	48.2	4.76	1127	5.40	34	10	6.2	-19.0					<0.10		1.06		<0.10		
	Average	**15.8**	**47.0**	**4.64**	**1132**	**5.37**	**37**	**10**	**5.8**	**-21.0**					**<0.10**		**1.09**		**<0.10**		
28 Hr	Bucket 2A-1	17.3	44.2	4.23	1155	5.86	48	15	8.5	-32.5					<0.10		1.08		<0.10		
	Bucket 2A-2	17.2	46.4	4.46	1149	5.85	44	15	9.6	-27.0					<0.10		1.16		<0.10		
	Bucket 2A-3	17.2	48.0	4.60	1146	5.85	41	15	9.5	-27.5					<0.10		1.07		<0.10		
	Average	**17.2**	**46.2**	**4.43**	**1150**	**5.85**	**44**	**15**	**9.2**	**-29.0**					**<0.10**		**1.10**		**<0.10**		
32 Hr	Bucket 2A-1	17.5	47.8	4.57	1214	6.23	78	20	7	-64.5					0.14		0.89		<0.10		
	Bucket 2A-2	17.5	52.0	4.96	1204	6.27	75	20	8	-60.5					<0.10		0.86		<0.10		
	Bucket 2A-3	17.4	57.2	5.46	1206	6.31	74	20	8	-59.5					<0.10		0.79		<0.10		
	Average	**17.5**	**52.3**	**5.00**	**1208**	**6.27**	**76**	**20**	**8**	**-61.5**					**0.14**		**0.85**		**<0.10**		
56 Hr	Bucket 2A-1	17.3	48.0	4.59	1224	6.59	84	20	7	-65.5					<0.10		0.84		0.11		
	Bucket 2A-2	17.2	53.7	5.14	1216	6.63	79	20	8	-59.5					<0.10		0.74		<0.10		
	Bucket 2A-3	17.3	57.3	5.49	1220	6.67	82	20	8	-59.0					<0.10		0.82		0.11		
	Average	**17.3**	**53.0**	**5.07**	**1220**	**6.63**	**82**	**20**	**8**	**-61.3**					**<0.10**		**0.80**		**0.11**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null

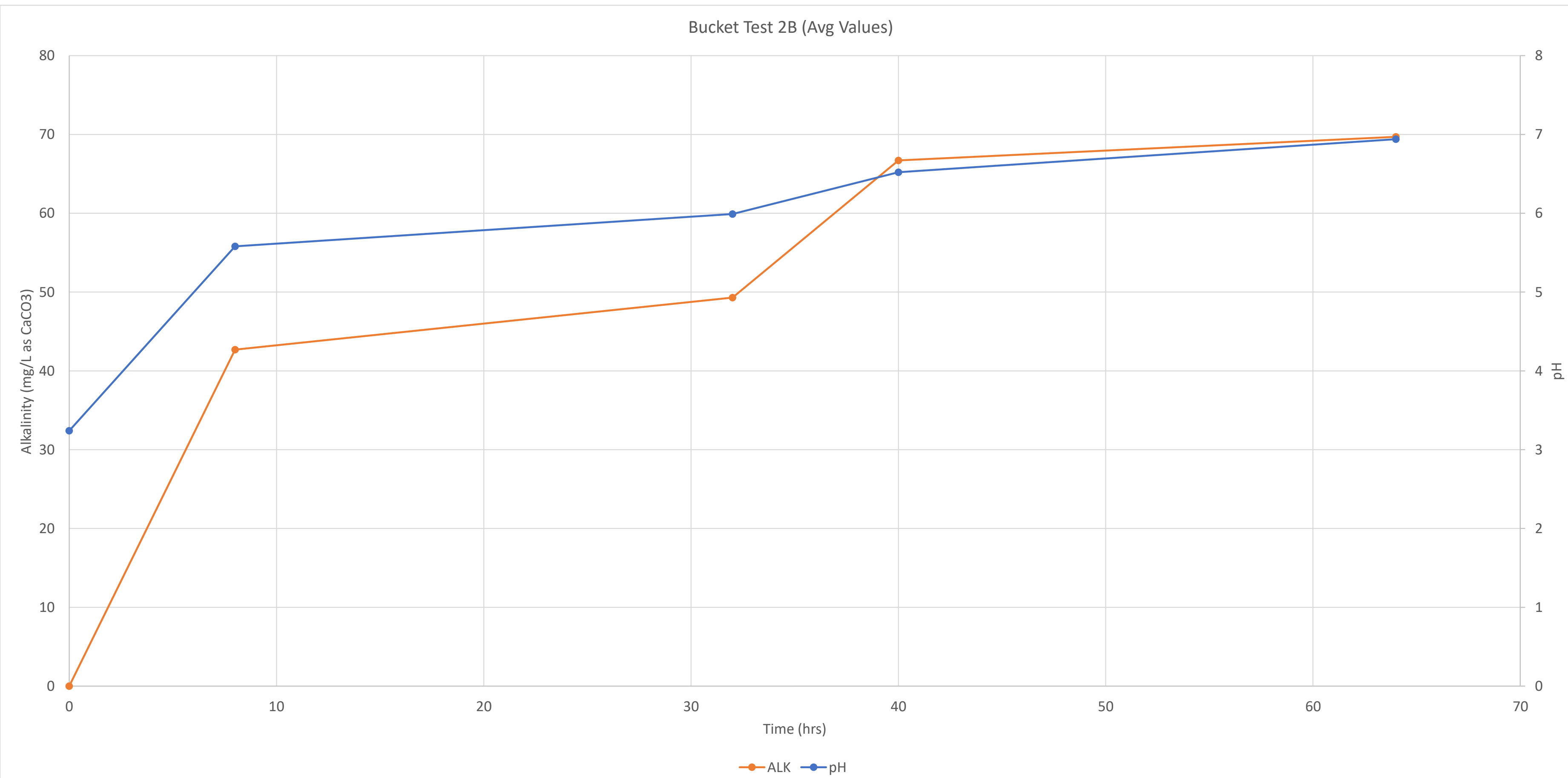


Bucket 2B Start Date: 7/10/2018 End Date: 7/13/2018 **Puritan Bench-Scale "Bucket" Test**

Method Gradually Add Water Over 8 HRS - Drain- Settle for 24 HRS - REPEAT Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp	D.O.	DO	SPC	pH	Alkalinity	H2SO4 Added	NaOH Added	Acidity	Lab PH	Cond.	Acidity	Total Fe	Dis. Fe	Total Mn	Dis. Mn	Total Al	Dis. Al	SO4	TSS
		(C)	(%)	(mg/L)	(µS/cm)	(field)		(mL)	(mL)	(mg/L as CaCO3)		(umhos)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Raw	Bucket 2B-1	14.3	39.4	4.02	1265	3.32	0	0	22.3	111.5	3.05	1324	112.24	7.06	6.91	1.2	1.17	7.24	7.13	664.4	<5
	Bucket 2B-2	14.4	41.8	4.26	1271	3.21	0	0	22.7	113.5	3.02	1340	112.24	6.88	6.85	1.18	1.17	7.13	7.13	643.2	<5
	Bucket 2B-3	14.4	42.9	4.36	1267	3.19	0	0	22.4	112.0	3.05	1320	109.45	7.08	6.88	1.21	1.18	7.32	7.15	652.4	10
	Average	**14.4**	**41.4**	**4.21**	**1268**	**3.24**	**0**	**0**	**22.5**	**112.3**	**3.04**	**1328**	**111.31**	**7.01**	**6.88**	**1.20**	**1.17**	**7.23**	**7.14**	**653.3**	**10**
8 Hr	Bucket 2B-1	17.7	36.0	3.42	1177	5.45	39	20	8.9	-55.5					0.54		1.23		0.35		
	Bucket 2B-2	17.8	39.4	3.73	1183	5.64	47	20	9.2	-54.0					0.49		1.29		0.3		
	Bucket 2B-3	17.7	39.8	3.78	1180	5.65	42	20	10.6	-47.0					0.53		1.34		0.38		
	Average	**17.7**	**38.4**	**3.64**	**1180**	**5.58**	**43**	**20**	**9.6**	**-52.2**					**0.52**		**1.29**		**0.34**		
32 Hr	Bucket 2B-1	16.9	36.4	3.51	1191	5.89	43	15	6.8	-41.0					0.39		1.38		<0.10		
	Bucket 2B-2	16.7	44.7	4.33	1197	6.06	54	15	6.1	-44.5					0.28		1.36		<0.10		
	Bucket 2B-3	16.9	45.4	4.38	1193	6.02	51	15	6.4	-43.0					0.30		1.33		<0.10		
	Average	**16.8**	**42.2**	**4.07**	**1194**	**5.99**	**49**	**15**	**6.4**	**-42.8**					**0.32**		**1.36**		**<0.10**		
40 Hr	Bucket 2B-1	17.6	45.8	4.36	1232	6.42	61	20	5.6	-72.0					0.10		1.29		<0.10		
	Bucket 2B-2	17.8	52.1	4.94	1245	6.54	72	20	4.9	-75.5					<0.10		1.31		<0.10		
	Bucket 2B-3	17.8	58.5	5.54	1243	6.61	67	20	5.9	-70.5					<0.10		1.28		<0.10		
	Average	**17.7**	**52.1**	**4.95**	**1240**	**6.52**	**67**	**20**	**5.5**	**-72.7**					**0.10**		**1.29**		**<0.10**		
64 Hr	Bucket 2B-1	17.5	53.0	5.05	1244	6.85	66	20	7.5	-62.5					<0.10		1.36		<0.10		
	Bucket 2B-2	17.3	56.7	5.43	1258	6.93	71	20	6.8	-66.0					<0.10		1.29		<0.10		
	Bucket 2B-3	17.1	59.8	5.73	1258	7.04	72	20	7.0	-65.0											
	Average	**17.3**	**56.5**	**5.40**	**1253**	**6.94**	**70**	**20**	**7.1**	**-64.5**					**<0.10**		**1.33**		**<0.10**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null

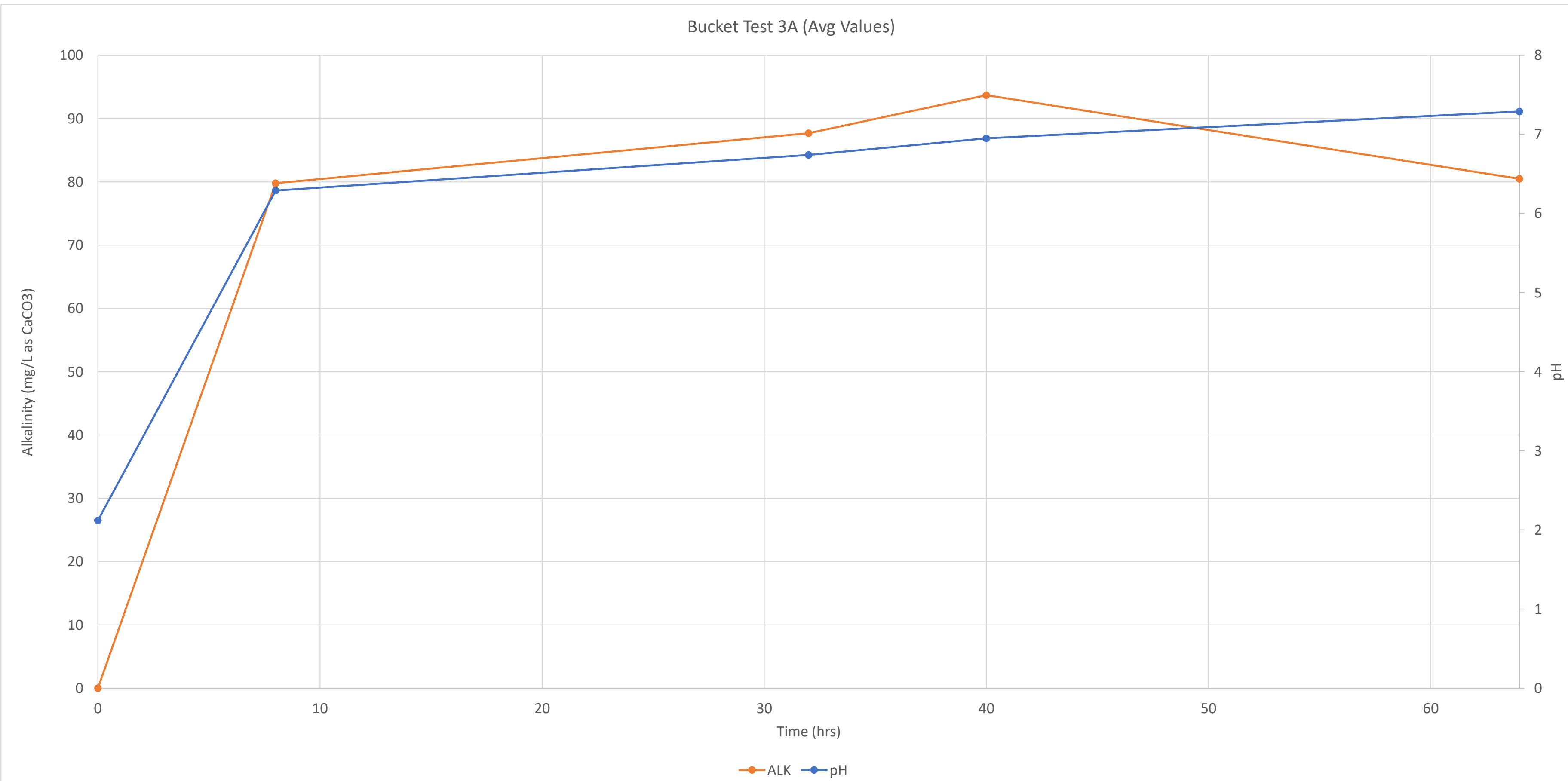


Bucket 3A Start Date: 4/23/2018 End Date: 4/26/2018 **Puritan Bench-Scale "Bucket" Test**

Method Add All Water at Once - Let Stand for 8 HRS - Drain- Let Settle for 24 HRS - REPEAT Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp (C)	D.O. (%)	DO (mg/L)	SPC (µS/cm)	pH (field)	Alkalinity	H2SO4 Added (mL)	NaOH Added (mL)	Acidity (mg/L as CaCO3)	Lab PH	Cond. (umhos)	Acidity (mg/L)	Total Fe (mg/L)	Dis. Fe (mg/L)	Total Mn (mg/L)	Dis. Mn (mg/L)	Total Al (mg/L)	Dis. Al (mg/L)	SO4 (mg/L)	TSS (mg/L)
Raw	Bucket 3A-1	10.5	69.2	7.7	1177	2.12	0				2.95	1294	112.24	4.17	4.15	1.33	1.26	12.34	11.94	759.6	<5
	Bucket 3A-2	10.5	69.2	7.7	1177	2.12	0				2.95	1288	111.64	4.27	4.22	1.37	1.32	12.12	11.89	722.7	<5
	Bucket 3A-3	10.5	69.2	7.7	1177	2.12	0				2.92	1293	112.63	4.29	4.18	1.33	1.33	12.2	12.1	657.4	<5
	Average	**10.5**	**69.2**	**7.7**	**1177**	**2.12**	**0**				**2.94**	**1292**	**112.17**	**4.24**	**4.18**	**1.34**	**1.30**	**12.22**	**11.98**	**713.2**	**<5**
8 Hr	Bucket 3A-1	16.4	71.1	6.93	1130	6.47	94	20	7.22	-63.9					<0.10		1.26		<0.10		
	Bucket 3A-2	16.3	72.3	7.06	1151	6.27	81.5	15	4.71	-51.5					<0.10		1.26		<0.10		
	Bucket 3A-3	16.3	72.9	7.1	1186	6.12	64	15	8.39	-33.1					<0.10		1.18		<0.10		
	Average	**16.3**	**72.1**	**7.03**	**1156**	**6.29**	**79.8**	**17**	**6.77**	**-49.5**					**<0.10**		**1.23**		**<0.10**		
32 Hr	Bucket 3A-1	17.3	66.9	6.4	1193	6.88	103	20	12.75	-36.3					<0.10		1.27		<0.10		
	Bucket 3A-2	17.3	65.1	6.6	1219	6.74	87	25	14.1	-54.5					<0.10		1.22		<0.10		
	Bucket 3A-3	17.4	69.2	6.6	1255	6.6	73	20	8.6	-57.0					<0.10		1.22		<0.10		
	Average	**17.3**	**67.1**	**6.5**	**1222**	**6.74**	**88**	**22**	**11.82**	**-49.3**					**<0.10**		**1.24**		**<0.10**		
40 Hr	Bucket 3A-1	17.3	70.5	6.73	1217	6.96	108.5	15	16.3	6.5					<0.10		1.09		<0.10		
	Bucket 3A-2	17.1	69	6.62	1291	6.95	92.5	20	10.25	-48.8					<0.10		1.07		<0.10		
	Bucket 3A-3	17	66.3	6.38	1351	6.94	80	20	11.25	-43.8					<0.10		1.06		0.1		
	Average	**17.1**	**68.6**	**6.58**	**1286**	**6.95**	**93.7**	**18**	**12.60**	**-28.7**					**<0.10**		**1.07**		**0.1**		
64 Hr	Bucket 3A-1	16	66.4	6.54	1228	7.34	88	20	12.4	-38.0					<0.10		1.09		0.1		
	Bucket 3A-2	16	66.7	6.54	1310	7.27	86	15	8.2	-34.0					<0.10		1.06		<0.10		
	Bucket 3A-3	16.1	66.6	6.55	1370	7.25	67.5	15	9.7	-26.5					<0.10		1.02		0.14		
	Average	**16.0**	**66.6**	**6.54**	**1303**	**7.29**	**80.5**	**17**	**10.1**	**-32.8**					**<0.10**		**1.06**		**0.12**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null



Bucket 3A Start Date: 6/11/2018 End Date: 6/14/2018

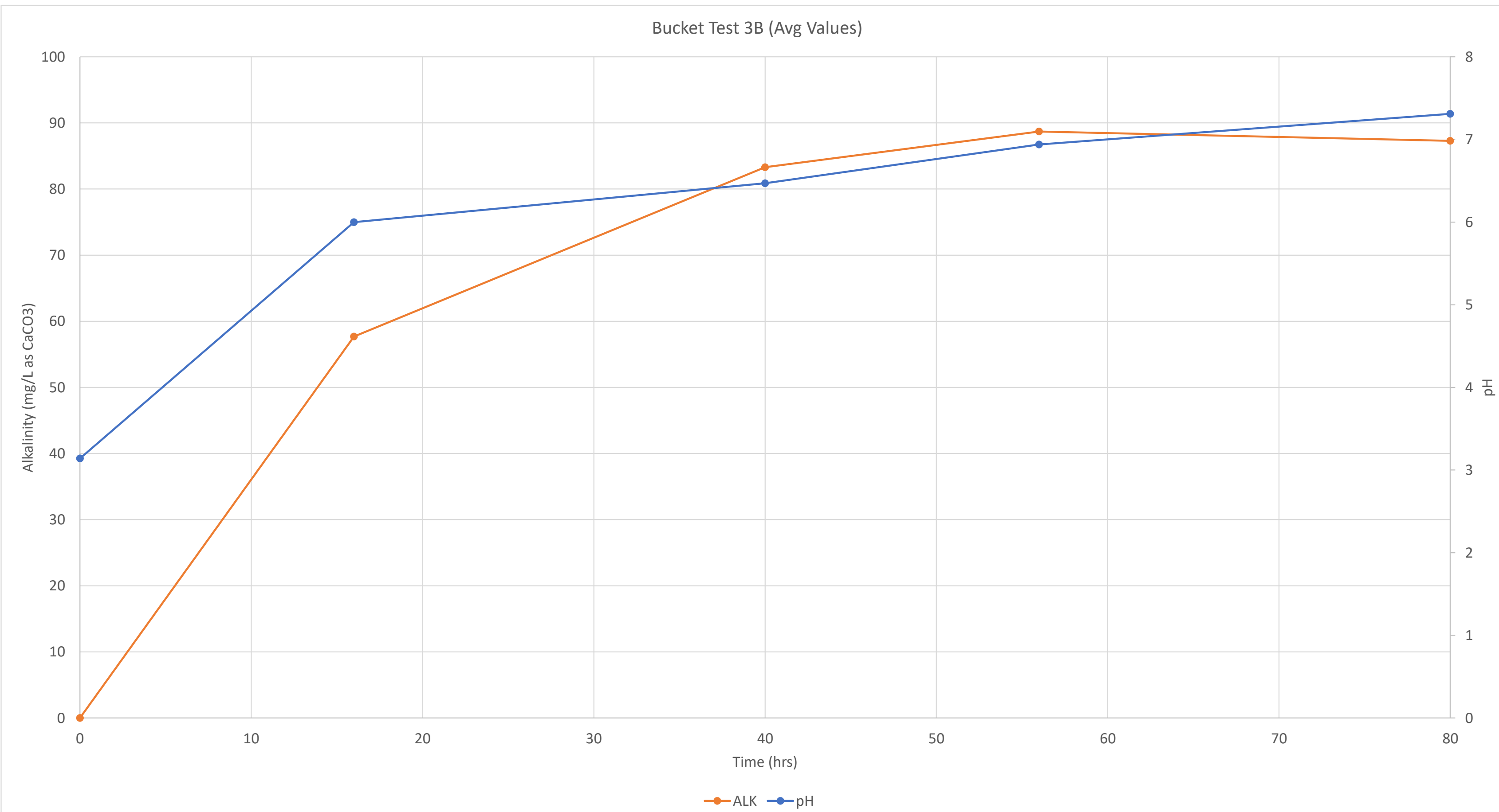
Puritan Bench-Scale "Bucket" Test

Method Gradually Add Water Over 16 HRS - Drain - Let Settle for 24 HRS - REPEAT

Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp	D.O.	DO	SPC	pH	Alkalinity	H2SO4 Added	NaOH Added	Acidity	Lab PH	Cond.	Acidity	Total Fe	Dis. Fe	Total Mn	Dis. Mn	Total Al	Dis. Al	SO4	TSS
		(C)	(%)	(mg/L)	(µS/cm)	(field)		(mL)	(mL)	(mg/L as CaCO3)		(umhos)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Raw	Bucket 3B-1	13.4	46.2	4.81	1261	3.26	0	0	23.1	115.5	3.08	1304	109.65	7.12	6.72	1.45	1.42	10.67	10.46	605.8	<5
	Bucket 3B-2	13	45.5	4.74	1283	3.09	0	0	23.2	116	3.07	1312	112.63	6.81	6.5	1.48	1.39	10.74	10.11	622.2	<5
	Bucket 3B-3	13.3	44.4	4.62	1281	3.07	0	0	22.9	114.5	3.09	1303	107.86	7.07	6.97	1.51	1.45	10.67	10.57	600.4	<5
	Average	**13.2**	**45.4**	**4.72**	**1275**	**3.14**	**0**	**0**	**23.1**	**115.3**	**3.08**	**1306**	**110.047**	**7**	**6.73**	**1.48**	**1.42**	**10.69**	**10.38**	**609.47**	**<5**
16 Hr	Bucket 3B-1	18.8	47.5	4.41	1265	5.92	69	25	6.0	-95					<0.10		1.43		<0.10		
	Bucket 3B-2	18.7	53.6	4.99	1258	6.08	48	15	5.1	-49.5					<0.10		1.42		<0.10		
	Bucket 3B-3	18.6	49.1	4.59	1250	6.00	56	20	5.2	-74					<0.10		1.46		<0.10		
	Average	**18.7**	**50.1**	**4.66**	**1258**	**6.00**	**58**	**20**	**5.4**	**-72.8**					**<0.10**		**1.44**		**<0.10**		
40 Hr	Bucket 3B-1	17.6	61.3	5.83	1278	6.40	79	25	2.8	-111					<0.10		1.47		<0.10		
	Bucket 3B-2	17.4	55.0	5.25	1273	6.52	90	25	2.8	-111					<0.10		1.4		<0.10		
	Bucket 3B-3	17.4	58.7	5.60	1267	6.48	81	25	3.6	-107					<0.10		1.43		<0.10		
	Average	**17.5**	**58.3**	**5.56**	**1273**	**6.47**	**83**	**25**	**3.1**	**-110**					**<0.10**		**1.43**		**<0.10**		
56 Hr	Bucket 3B-1	19.0	63.0	5.82	1310	6.84	91	30	1.8	-141					<0.10		1.26		<0.10		
	Bucket 3B-2	18.9	59.1	5.47	1304	7.00	87	30	4.0	-130					<0.10		1.18		0.1		
	Bucket 3B-3	18.9	59.0	5.46	1314	6.98	88	30	3.6	-132					<0.10		1.29		<0.10		
	Average	**18.9**	**60.4**	**5.58**	**1309**	**6.94**	**89**	**30**	**3.1**	**-134**					**<0.10**		**1.24**		**0.1**		
80 Hr	Bucket 3B-1	18.9	64.8	5.99	1320	7.21	84	30	6.4	-118					<0.10		1.29		0.11		
	Bucket 3B-2	18.8	59.4	5.51	1316	7.34	86	25	2.8	-111					<0.10		1.21		0.1		
	Bucket 3B-3	18.8	55.6	5.16	1323	7.37	92	25	2.5	-112.5					<0.10		1.27		<0.10		
	Average	**18.8**	**59.9**	**5.55**	**1320**	**7.31**	**87**	**27**	**3.9**	**-113.8**					**<0.10**		**1.26**		**0.11**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null



Bucket 4A Start Date: 7/18/2018 End Date: 7/21/2018

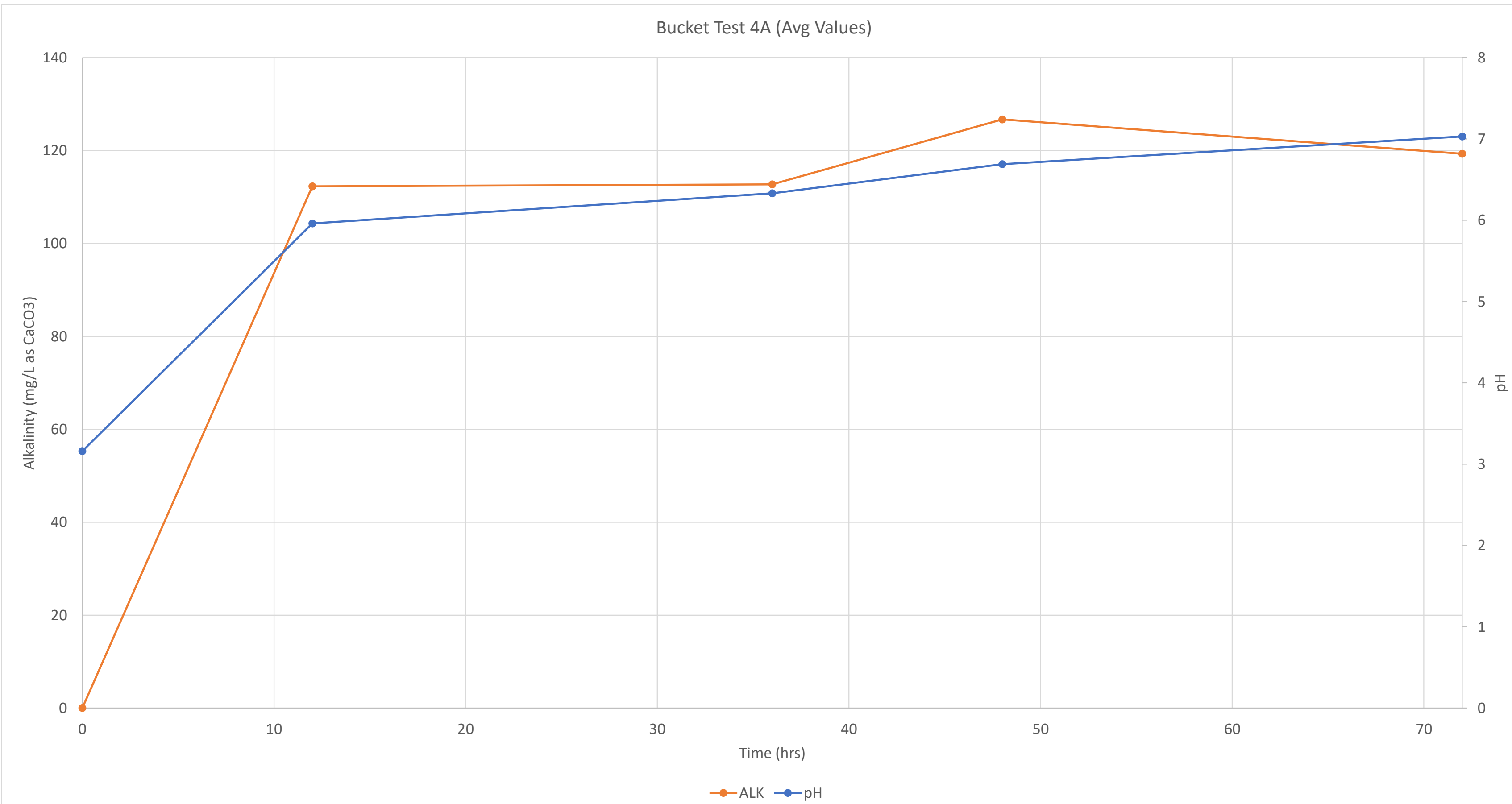
Puritan Bench-Scale "Bucket" Test

Method Add All Water at Once - Let Stand for 12 HRS - Drain (sample) - Settle for 24 HRS - REPEAT

Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp	D.O.	DO	SPC	pH	Alkalinity	H2SO4 Added	NaOH Added	Acidity	Lab PH	Cond.	Acidity	Total Fe	Dis. Fe	Total Mn	Dis. Mn	Total Al	Dis. Al	SO4	TSS
		(C)	(%)	(mg/L)	(µS/cm)	(field)		(mL)	(mL)	(mg/L as CaCO3)		(umhos)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Raw	Bucket 4A-1	12.4	44.6	4.75	1291	3.19	0	0	23.1	115.5	2.91	1309	112.63	4.65	4.6	1.42	1.4	12.49	12.48	762.1	<5
	Bucket 4A-2	12.3	43.2	4.6	1296	3.16	0	0	23.3	116.5	2.92	1307	110.05	4.49	4.43	1.38	1.32	12.61	12.21	744.3	<5
	Bucket 4A-3	12.3	44.6	4.76	1295	3.14	0	0	23.3	116.5	2.91	1295	114.03	4.39	4.39	1.38	1.34	12.12	11.82	727.6	5
	Average	**12.3**	**44.1**	**4.70**	**1294**	**3.16**	**0**	**0**	**23.2**	**116.2**	**2.91**	**1304**	**112.24**	**4.51**	**4.47**	**1.39**	**1.35**	**12.41**	**12.17**	**744.67**	**5**
12 Hr	Bucket 4A-1	17.0	40.4	3.89	1308	5.93	120	30	4.2	-129					<0.10		1.31		0.15		
	Bucket 4A-2	16.9	40.5	3.90	1299	5.95	111	30	4.3	-128.5					<0.10		1.28		0.14		
	Bucket 4A-3	16.8	43.1	4.17	1291	6.01	106	30	8.4	-108					<0.10		1.26		0.2		
	Average	**16.9**	**41.3**	**3.99**	**1299**	**5.96**	**112**	**30**	**5.6**	**-121.8**					**<0.10**		**1.28**		**0.16**		
36 Hr	Bucket 4A-1	17.1	42.1	4.04	1318	6.32	114	30	7.8	-111					<0.10		1.32		0.1		
	Bucket 4A-2	17.1	43.5	4.18	1311	6.31	117	30	8.2	-109					<0.10		1.23		0.1		
	Bucket 4A-3	17.0	48.3	4.65	1304	6.36	107	25	4.8	-101					<0.10		1.23		<0.10		
	Average	**17.1**	**44.6**	**4.29**	**1311**	**6.33**	**113**	**28**	**6.9**	**-107**					**<0.10**		**1.26**		**0.1**		
48 Hr	Bucket 4A-1	17.3	46.1	4.42	1345	6.65	124	35	6.1	-144.5					<0.10		1.08		0.13		
	Bucket 4A-2	17.3	51.0	4.88	1349	6.68	132	35	6.7	-141.5					<0.10		1.01		<0.10		
	Bucket 4A-3	17.3	55.0	5.27	1341	6.73	124	35	9.4	-128					<0.10		0.96		<0.10		
	Average	**17.3**	**50.7**	**4.86**	**1345**	**6.69**	**127**	**35**	**7.4**	**-138.0**					**<0.10**		**1.02**		**0.13**		
78 Hr	Bucket 4A-1	17.3	47.4	4.54	1352	7.00	120	30	6.6	-117					<0.10		1.11		0.1		
	Bucket 4A-2	17.2	53.1	5.10	1357	7.01	122	30	5.6	-122					<0.10		1		<0.10		
	Bucket 4A-3	17.1	57.2	5.49	1348	7.07	116	30	7.4	-113					<0.10		0.95		<0.10		
	Average	**17.2**	**52.6**	**5.04**	**1352**	**7.03**	**119**	**30**	**6.5**	**-117**					**<0.10**		**1.02**		**0.1**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null



Bucket 4B Start Date: 4/29/2018 End Date: 5/3/2018 **Puritan Bench-Scale "Bucket" Test**

Method Gradually Add Water Over 24 HR Period - Drain to empty Bucket - Lets Stand for 24 HR - REPEAT

Sesononed Limestone from Original FeAlMn Bed & Puritan AMD

		Bucket Data - Conducted by SFU						Hot Acidity - Conducted by SFU			Lab Analysis - Conducted by G&C Labs										
		Temp	D.O.	DO	SPC	pH	Alkalinity	H2SO4 Added	NaOH Added	Acidity	Lab PH	Cond.	Acidity	Total Fe	Dis. Fe	Total Mn	Dis. Mn	Total Al	Dis. Al	SO4	TSS
		(C)	(%)	(mg/L)	(µS/cm)	(field)		(mL)	(mL)	(mg/L as CaCO3)		(umhos)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Raw	Bucket 4B-1	14.1	54.5	5.58	1285	3.14	0	0	23.5	117.5	2.99	1324	124.38	5.3	4.86	1.63	1.43	12.81	12.67	643.9	<5
	Bucket 4B-2	13.4	56.5	5.86	1288	3.13	0	0	23.5	117.5	2.97	1338	129.95	5.28	5.05	1.61	1.46	13.07	12.9	591	<5
	Bucket 4B-3	13.6	56.7	5.87	1287	3.12	0	0	23.5	117.5	2.69	1348	117.61	5.31	5.06	1.63	1.43	13.12	12.93	649.8	<5
	Average	**13.7**	**55.9**	**5.77**	**1287**	**3.13**	**0**	**0**	**23.5**	**117.5**	**2.88**	**1337**	**123.98**	**5.30**	**4.99**	**1.62**	**1.44**	**13.00**	**12.83**	**628.2**	**<5**
24 Hr	Bucket 4B-1	18.8	54.0	5.00	1276	6.10	92	25	6	-95					<0.10		1.46		<0.10		
	Bucket 4B-2	18.7	56.9	5.29	1277	6.11	96	25	5	-100					<0.10		1.39		<0.10		
	Bucket 4B-3	18.7	54.9	5.14	1259	6.07	90	25	9.6	-77					<0.10		1.39		<0.10		
	Average	**18.7**	**55.3**	**5.14**	**1271**	**6.09**	**93**	**25**	**6.9**	**-91**					**<0.10**		**1.41**		**<0.10**		
48 Hr	Bucket 4B-1	17.2	55.9	5.36	1288	6.42	96	25	7.7	-86.5					<0.10		1.47		<0.10		
	Bucket 4B-2	17.1	57.2	5.48	1290	6.46	100	25	6.7	-91.5					<0.10		1.39		<0.10		
	Bucket 4B-3	17.2	55.3	5.30	1273	6.41	91	20	3.7	-81.5					<0.10		1.37		<0.10		
	Average	**17.2**	**56.1**	**5.38**	**1284**	**6.43**	**96**	**23**	**6.0**	**-86.5**					**<0.10**		**1.41**		**<0.10**		
72 Hr	Bucket 4B-1	17.6	64.3	6.11	1320	6.85	97	30	7.4	-113					<0.10		1.12		<0.10		
	Bucket 4B-2	17.6	60.5	5.75	1319	6.92	105	30	3.0	-135					<0.10		1.06		<0.10		
	Bucket 4B-3	17.6	61.3	5.84	1305	6.90	100	30	7.2	-114					<0.10		1.05		<0.10		
	Average	**17.6**	**62.0**	**5.90**	**1315**	**6.89**	**101**	**30**	**5.9**	**-121**					**<0.10**		**1.08**		**<0.10**		
96 Hr	Bucket 4B-1	16.7	58.5	5.64	1317	7.13	122	20	3	-85					<0.10		1.13		0.11		
	Bucket 4B-2	16.6	65.6	6.33	1321	7.21	97	21	2.5	-92.5					<0.10		1.02		0.12		
	Bucket 4B-3	16.6	64.8	6.28	1309	7.19	100	20	3	-85					<0.10		0.97		<0.10		
	Average	**16.6**	**63.0**	**6.08**	**1316**	**7.18**	**106**	**20**	**2.8**	**-87.5**					**<0.10**		**1.04**		**0.12**		

Note: Values with a "<" symbol are below lab detection limits and when calculating averages are treated as null