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August 31, 2018

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

**RE: Final Report for Midwest AgEnergy Group / NDIC Renewable Energy Development Fund Grant
Contract Number R-0137-046.**

Ms. Fine:

Please find enclosed the final report for Project R-0137-046 for Barley Protein Concentrate. As per the agreement scope of work the enclosed deliverables include:

- Results of the study of the supply and costs of feed barley grown in ND and its availability as a feedstock for protein concentrate and advanced biofuels;
- Results of the market opportunity study for barley protein concentrate in aquaculture, including the size, scale, logistics, and dynamics of the aquaculture market;
- Report on the engineering study regarding integration feasibility and design equipment specifications with a +/- 30% cost estimate.
- Report on the likelihood of receiving an advanced biofuel designation and the pathway for achieving all required regulatory approvals.

If you have any questions regarding this report please contact me at 701-442-7503 or at adunlop@midwestagenergy.com.

Sincerely:

A handwritten signature in blue ink that reads "Adam C Dunlop".

Adam C Dunlop
Director Technical Services
Midwest AgEnergy Group





Barley Protein Concentrate

Final Report

August 31, 2019

Contract R-037-046

This report was prepared by Midwest AgEnergy Group pursuant to an agreement with the Industrial Commission of North Dakota, which partially funded the project through the Renewable Energy Program.

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Project Summary

The intent of the project was to provide feasibility information regarding use of ND barley to produce a high value barley protein concentrate (BPC) designed for aquaculture as well as a low carbon advanced biofuel. The first phase of the project was to demonstrate the feasibility of scaling up of a technology owned by Montana Microbial Products (MMP) and integrating it into the Dakota Spirit AgEnergy (DSA). Feasibility was evaluated based on: a market study on the availability of barley, market analysis of BPC and low carbon advanced biofuels, front end engineering and integration strategies and cost estimates, and an evaluation of regulatory requirements necessary to bring these products to market. The project was able to be completed in a time and manner which accomplished the feasibility study objectives.

ND has a long history of raising barley for feed and malt applications. The recent exit of a significant barley buyer in the Spiritwood area leaves an opening for a replacement buyer. Market conditions over the last three years suggest a protein concentration project can offer a competitive cash flow cropping option for barley growers and maintain feedstock costs low enough to achieve satisfactory processing margins.

There is a strong demand for high protein products in commercial animal raising operations. BPC value is believed to correlate to #2 fishmeal as it has unique characteristics which may allow it to serve as direct replacement in carnivorous fish diets. Fishmeal has traded in the range of \$750-\$2000/ton since 2008. World demand for fish meal substitute is estimated at about 650,000 metric tons.

Multiple integration opportunities for the BPC process into DSA's current operation were determined. The primary case studied will allow existing plant to maintain current production levels and add/integrate the protein production facility with capacity of up to 30,200 tons BPC per year. Capital cost estimates provided by Fluid Quip Process Engineering (FQPT) for feasibility level design and integration were higher than anticipated at about \$65 million for primary case. Additional design configurations were examined to determine opportunities to reduce construction costs and maintain production capacity for BPC and the existing corn ethanol plant.

BPC in existing form has cleared regulatory requirements to be marketed in the US. Additional approvals are required to market in Canada and worldwide. The production of ethanol from barley meeting the definition of an advanced biofuel is likely. Selection of a final design and refined mass energy balance are necessary to determine the value of carbon intensity reduction and ensure the biofuel will be considered advanced.

The standards of the project feasibility study have been met. As this was only feasibility level, further discovery will be required. Areas requiring additional research or expertise identified in this project include the value of the BPC product in the aquaculture market and strategies for reducing capital expenditures. It is our intention to continue to refine value model assumptions on fishmeal substitutes in the aquaculture market and further evaluate options to reduce the expected capital and operational costs. These further examinations are beyond the scope of the phase 1 feasibility required for this project.

MAG Barley Origination Study for Spiritwood, ND

The full Barley origination study performed by MAG is located in Appendix A.

In general we believe we can secure the approximately 6.5 million bushels of barley required to feed the proposed project. The recent departure of a large barley purchaser in ND will further erode demand in 2019. The entire volume required may not be immediately available and MAG may need to create acreage contracts commonly utilized by maltsters to ensure adequate production at desired economics. There is no futures market for barley so developing tools for managing risk exposure to the project will be critical. The following bullets summarize knowledge gained while investigating opportunities for barley origination in the Spiritwood ND area.

- Procuring barley supply will put MAG in competition with malting barley buyers in ND.
- Historic abandonment of barley culture has been in response to stagnant demand from maltsters. As recently as ten years ago, ND barley area was over 1.5 million acres, compared to 0.4 million acres in 2017. At full scale, the project envisions demand for production from about 75,000 acres. There should be ample room to enter the ND barley market alongside existing malting demand.
- Determining a contract price to offer growers will require MAG to bid the price that gives farmers a competitive cash flow with other crops, primarily spring wheat.
- Market conditions over the last three years suggest barley for this project can offer a competitive cash flow cropping option for producers.
- Higher carryover stocks of barley tend to depress the price of spot barley and widen the premium of malting barley over feed quality. We must monitor the ND barley supply/demand balance to help anticipate the spread between feed quality and malting quality barley year-over-year.
- Feed barley prices are correlated with corn prices in ND. This means corn futures may be a possible option to fix prices, or to un-fix prices of barley when necessary.
- Due to differences in specifications for our barley (protein content), farmers may see an agronomic opportunity to maximize yields and lower their cost of production by contracting with MAG.
- We may specify varieties and promote production practices that exclude our product from the market for malting barley. That will shelter our market from large price swings in malting barley within a crop year.
- There is only intermittent correlation between feed grain and protein meal prices. We will need to segregate our risk management activities between those markets

In summary, ND has a long history of raising barley for feed and malt applications. Analysis of market conditions over the last three years suggest a protein concentration project can offer a competitive cash flow cropping option for barley growers and maintain feedstock costs low enough to achieve satisfactory processing margins at around \$4.00 per bushel.

Front End Engineering & Design/ Integration Study:

Fluid Quip Process Technologies (FQPT) was retained to complete a FEL1 engineering study to evaluate a scaled up installation of Montana Microbial Products (MMP) Barley Protein Concentrate (BPC) technology at Dakota Spirit (DSA) at the Spiritwood, ND location. The scope included determining opportunities for integration with existing plant for production of between 15,000 and 25,000 tons per year of BPC. FQPT was also to ascertain equipment and design specifications resulting in a +/- 30% cost estimate for the project.

The integration opportunity determined more BPC could be produced than originally anticipated without decreasing the current plant production rate. The study showed potential for barley input of about 18,000 bushels per day which would produce about 30,240 tons per year of BPC and just under 13.5 million gallons of ethanol. Integration of most utilities is possible with minimal expansion. Alcohol process streams from the barley and corn plants can be comingled if additional capacity is added to the existing plant. A Process Flow Diagram for BPC integration into DSA is available in Appendix B.

The BPC requirements include:

- Barley dump
- Barley storage
- Barley dehulling system
- Dehulled barley storage
- Barley hammer milling system
- Slurry blending system
- Liquefaction system
- Saccharification system
- Heat exchangers
- Fermentation with coolers and a beer well
- Barley CO₂ Scrubber
- Barley Propagation system
- Barley beer column
- Barley 1st and 2nd effect evaporator with surface condenser
- Molecular sieves
- Whole Stillage tank
- Centrifuge and required conveyance to dryer
- BPC dryer
- BPC product cooling system
- BPC 5x5 RTO
- BPC supersacker equipment and warehouse
- BPC bulk silo
- BPC conveyance to existing bulk weigher
- Cooling tower cell addition with pump

A general arrangement map was prepared showing locations of the required process areas at DSA. It is shown in Appendix C.

The FEL 1 total project cost estimate deliverable from FQPT exceeded the +/- 30% criterion specified in the contact. FQPT provided a +/- 15% estimate inclusive of taxes, freight, project consumables, material, labor, detailed engineering, construction management, and equipment spares for the BPC plant. The total project estimate was \$65,234,396.

A second round of value engineering was undertaken to discover opportunities to decrease capital expenditures. This process involved reducing the input and product storage capacity as well as shrinking process flexibility. Considerations also included alternatives for reduced capacity in DDE. Access to firm natural gas supply could enable savings on drying equipment capital expenditures. Total inclusive cost post value engineering ranged from \$43.8 million to \$53.8 million. It is unlikely all cost reduction strategies can be concurrently implemented without negatively impacting the reliability of BPC plant operations.

BPC Market Analysis Summary

A comprehensive BPC Market Analysis is available in Appendix D.

The need to feed the world's growing human population is a much discussed and well documented issue. Growing prosperity among the world's developing economies is increasing food consumption per capita, in addition to the growing population numbers. Thus the desire for meat and protein to accommodate the demand in the human diets will continue to increase.

Fish are the most efficient converters of feed to protein. Salmon and catfish in aquaculture settings approach 1:1 Feed Conversion Ratio. Fish protein is a healthy alternative to red meat, with lower levels of fat, saturated fat and cholesterol. Species such as Salmon are a leading source of heart healthy omega 3 fatty acids which help to lower low density lipid ("bad" cholesterol) levels in humans.

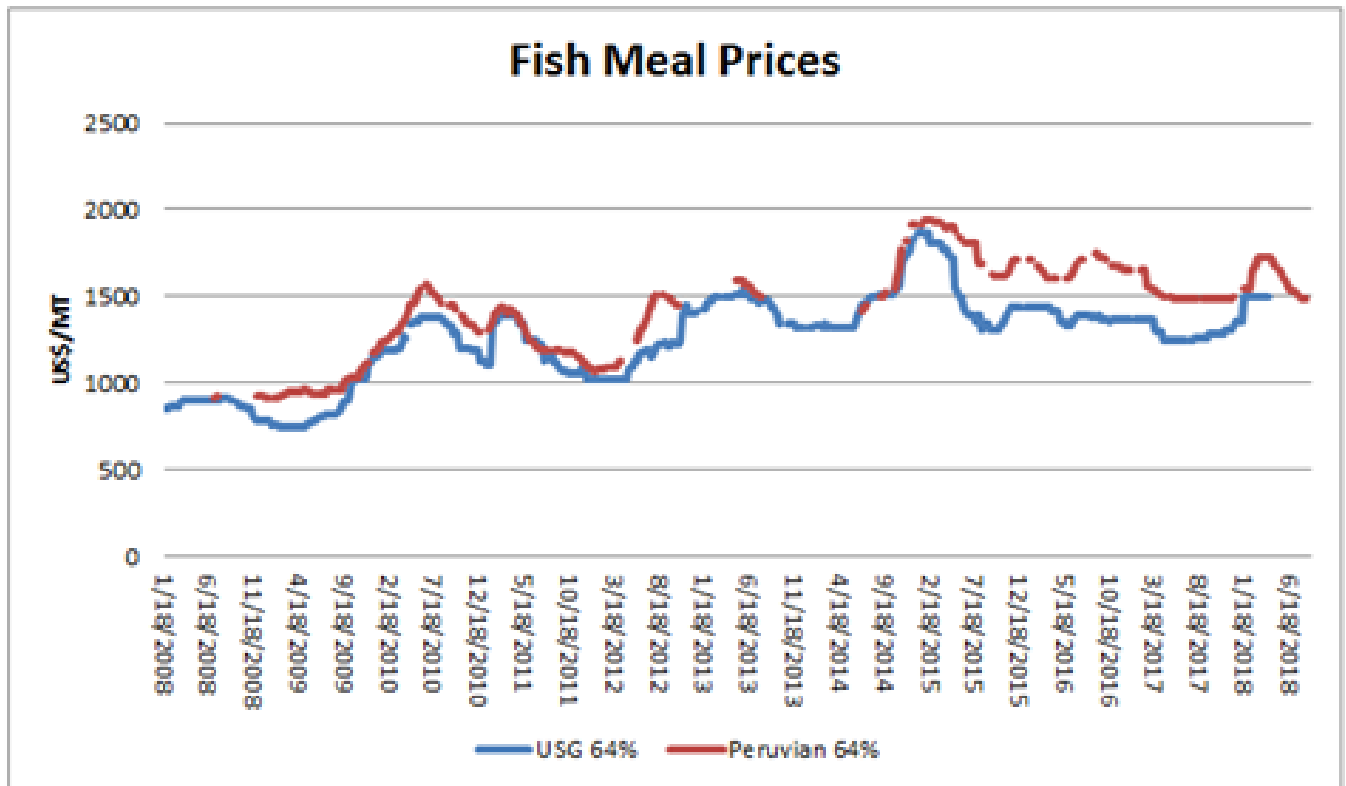
According to the United Nations Food and Agriculture Organization (FAO), the supply of wild-caught fish is peaking. Since the mid-1980's fish capture has held almost steady in the world. All of the increase in fish food supplies since the mid-1980's has been attributable to the rise of farmed fish-aquaculture. Aquaculture fish production has grown at a compounded rate of 3% per year from 1985. Farmed fish supplied 48% of all fish consumption in 2015, according to FAO.

Salmon and trout need high quality diets, which have typically contained 35-45% fish meal. Small fish that generally supply the fish meal market are wild-caught and now face the same overfishing threats the species caught for human consumption face. The peak in whole fish supply for fish meal came in 1994 when 30 Mmt of fish were processed into meal. In 2016 that volume had declined to 15 Mmt. FAO estimated worldwide fish meal production in 2016 at 4.45 Mmt. As availability of fish meal has declined, prices have increased. The outlook for the future is for stable harvests of small pelagic fish that supply the fish meal market. Countries are placing quotas on the annual "trash fish" catch to shield the ocean's

resources from complete depletion. With farmed fish production expected to grow nearly 14 Mmt by 2030, the pressure on fish meal supply will be felt in higher prices. This creates an incentive to find alternatives to fish meal that can be substituted for fish meal in aquaculture diets. The requirements for substitute feeds are that they are nutritionally balanced, palatable, water stable and, of course, economical compared to fish meal.

Dedicated research done by RAFOA (Research on Alternatives to fish Oil in Aquaculture at the University of Scotland) and PEPPA (Perspectives of Plant Protein Use in Aquaculture coordinated by the French National Institute for Agricultural Research) suggest that alternative protein sources may replace 20 to 25 percentage points of fish meal in salmonid rations. The largest commercial trout farm in the US has done commercial trials with BPC and is convinced that it can be substituted for fish meal up to 30% of total diet inclusion, with minimal or no additional supplementation.

Fishmeal has traded in the range of \$750-\$2000/ton since 2008. BPC value is believed to correlate to #2 fishmeal since, as indicated above, it may serve as direct replacement in carnivorous fish diets. We estimate reasonable world demand for fish meal substitute to be about 650,000 metric tons. Major domestic fish farms have indicated they are willing to pay full value of #2 fish meal for BPC.



Regulatory Review

Barley Starch RFS 2 Pathway

In order to qualify as an advanced biofuel a renewable fuel must be derived from something other than corn starch and have lifecycle greenhouse gas emissions at least 50% less than baseline lifecycle greenhouse gas emissions. EPA has evaluated a theoretical new barley dry mill facility using 100% natural gas for process heating and grid electricity and expected 39.1 kg CO₂ per mmBtu of fuel ethanol produced. This equates to about a 47% GHG reduction compared to baseline. Thus the theoretical plant fell just short of qualifying for advanced biofuel production.

The DSA corn ethanol plant purchases steam for thermal needs directly from Spiritwood Station. Because of this relationship the plant has no boiler or associated emissions and has been recognized by EPA to be more efficient than a traditional ethanol plant when pursuing its RFS corn based pathway. For reference DSA Fuel Production component for the existing ethanol plant was about 29 kg CO₂ per mmBtu of fuel ethanol produced (vs the 39.1 kg from hypothetical barley plant).

A company called Montana Advanced Biofuels (MAB) petitioned EPA for a pathway taking barley starch and converting it into ethanol using dry grind technology. EPA relied on information provided by MAB along with data originally published in the July 23, 2013 FR (78 FR 44075 aka the "Barley NODA) to perform analysis. EPA indicated the pathway would count for D6 RINs (traditional ethanol) and could also generate D5 RINs (advanced ethanol) based on usage limits of natural gas and electricity per gallon of ethanol produced. The pathway was approved on November 20, 2015 and called the "Advanced MAB Barley Process". The facility has not been constructed so demonstration of advanced biofuel from barley feedstock has not yet been demonstrated in commercial production in the US.

According to EPA methodology, in order to qualify the MAB pathway for Advanced D5 RINs the process must be based on dry mill technology and use no more than 0.84kWh and less than 30,700 Btu of natural gas per gallon. The fuel production assumes 2.16 gallon per 48 lb dehulled bushel on dry matter basis.

Mass Energy Balance prepared by FQPT for the BPC process indicates about 27,800 Btu/gal of thermal energy will be required and about 2 kW/gal based on connected kW. We can assume actual electrical kWh usage will be less than connected power. Yield is assumed to be 2.07 gal per 48 pound bushel of Hulled barley at 13.5% moisture.

Based on the information above it remains likely that advanced biofuel can be created from the starches fermented in the BPC process. Intricacies of determining the appropriate co-product credit for BPC have not yet been evaluated but could also play an important role in reducing the fuel carbon Intensity. A more detailed energy consumption evaluation and further definition of yield along with EPA input on methodology will be required to fully determine if the biofuel produced in the MMP process can be characterized as Advanced.

Feed Requirements

In order to commercially sell BPC as animal feed it must be recognized as a safe feed ingredient. A feed ingredient is a component part or constituent or any combination/mixture added to and comprising the feed. Feed ingredients include grains, milling byproducts, added vitamins, minerals, fats/oils, and other nutritional and energy sources. Legally, under the United States Federal Food, Drug, and Cosmetic Act (FFDCA) any substance that is added to or is expected to become a component of animal food, either directly or indirectly, must be used in accordance with a food additive regulation unless it is generally recognized as safe for that use (GRAS).

A Feed Ingredient must be registered with Food and Drug Administration (FDA) Center for Veterinary Medicine (CVM), and recognized by the Association of American Feed Control Officials (AAFCO). AAFCO is particularly important as for interstate commerce as it is tasked with developing and implementing uniform and equitable laws, regulations, standards, definitions and enforcement policies for regulating the manufacture, labeling, distribution and sale of animal feeds -resulting in safe, effective and useful feeds by promoting uniformity amongst member agencies.

MMP completed the necessary efforts to add BPC, called Barley Distillers Protein Concentrate (BDPC) to the AAFCO official publication in 2014. The current version contains BPC along with the most complete list of feed ingredients and their definitions.

Federal regulations require ingredients be listed on the product label by their common or usual name. A common or usual name is one that accurately identifies or describes the basic nature of the ingredient. FDA has recognized the definitions as they appear in the Official Publication of AAFCO as the common or usual name for animal feed ingredients including pet food.

MMP has completed the necessary label information and AAFCO registrations for BPC to be sold domestically. Barley Hulls, Barley Distillers Grains with Solubles, and Barely Distillers Syrup are also already included in AAFCO registration should they need to be sold independently as part of this project.

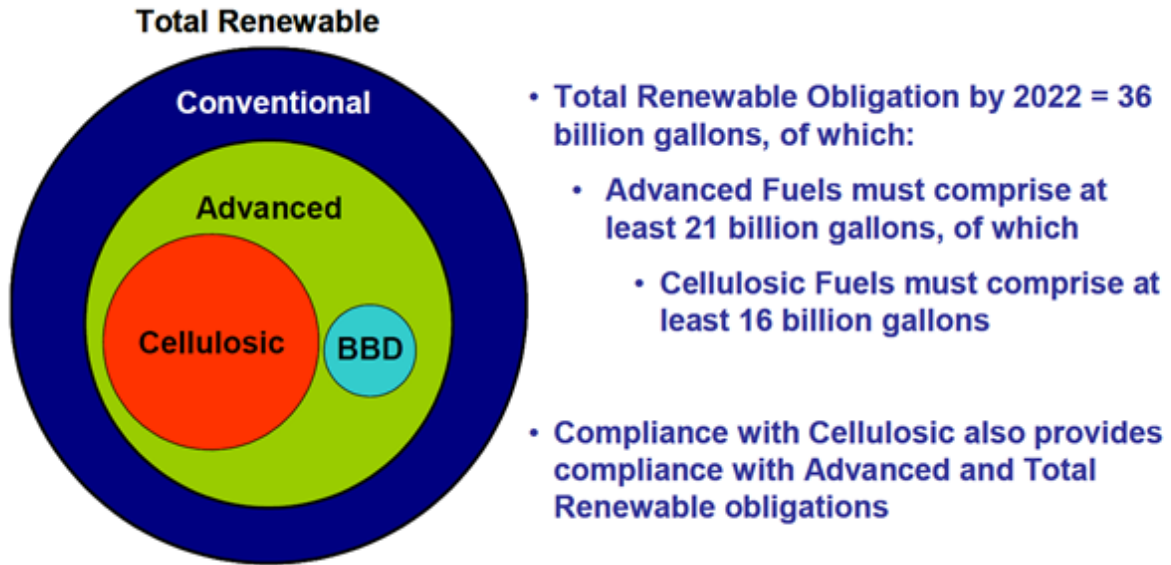
Additional registrations and certifications will be necessary to gain access to International markets. If the project progresses to phase 2, the project will include prioritization around registration and any additional feed trials required to market BPC internationally. Canadian market access will likely be the initial focus as it is proximal to proposed plant location and demand that greatly surpasses domestic salmonid demand potential.

Advanced & Low Carbon Fuel Market Summary

Renewable Ethanol produced from the BPC process can potentially be considered an advanced biofuel. (See Regulatory Review.) Advanced or low carbon ethanol biofuels are typically more valuable than traditional corn based ethanol gallons. The premium is driven by being designated as an advanced biofuel under the Renewable Fuel Standard (RFS) and/or achieving lifecycle carbon intensity levels lower than the baseline for traditional biofuels in markets which have low carbon fuel standards such as California.

The RFS sets levels of renewable fuel consumption for each year. Target volumes were set forth by

Congress in the original rule through 2022. EPA has some discretion over the prescribed targets and is tasked with determining the appropriate volumes after 2022. The volume standards are nested such that RINs produced from more elite processes and with lower lifecycle carbon scores fulfill multiple requirements. Cellulosic and Biodiesel are nested within the Advanced Biofuel category. See illustration below.



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Ethanol from sugar cane is the other major source of advanced biofuel available in significant commercial quantities. If ethanol produced from the BPC process is categorized as advanced biofuel by EPA, the value of an advanced RIN over a conventional RIN is an indicative measurement of additional value. The average premium for an advanced RIN over a traditional RIN has been about \$0.18 since 2015 as shown below.



The unspecified volume of the advanced biofuel requirement will be met by the most cost effective option. Historically biodiesel production has expanded beyond the mandated levels to comprise the majority of advanced biofuel, with brief periods of sugar cane ethanol imports from Brazil also filling this niche. The cost to bring biodiesel into the market has traditionally been influenced by biodiesel blender’s tax credit which has been intermittently renewed by Congress. If in subsequent years the tax credit is not renewed the RIN value for advanced biodiesel will likely need to increase to a 40-75 cent premium over conventional RINs to drive production up to mandated levels.

The California Low Carbon Fuel Standard (LCFS) program is intended to reduce the carbon intensity of transportation fuel pool 20% by 2030, reduce petroleum dependency, and generally transform and diversify the fuel pool in California.

Each motor fuel used in California is assigned as specific carbon intensity based on a lifecycle assessment. Credits may be generated for the amount of carbon intensity reductions a renewable fuel provides versus the baseline fuel of gasoline blend stock (CARBOB). Through a cap and trade program credit generators are can sell carbon reduction credits to other parties who may require them for compliance. The price of carbon credits is capped at \$200 per ton.

EPA has two approved pathways listed for ethanol produced from barley with net emissions of 48.2 and 52.1 kg CO2e per mmBtu. Assuming there is strong correlation between EPA Lifecycle Analysis and the California LCFS pathway evaluation allows calculation of the approximate additional CI value for advanced BPC ethanol in California. A summary of potential value created using the net emissions for barley ethanol specified by EPA and a range of California carbon credit values is depicted below.

CI Value of Ethanol	48.2	52.1
Carbon Value (\$/MT)	\$/gallon	\$/gallon
50	\$ 0.127	\$ 0.112
75	\$ 0.191	\$ 0.167
100	\$ 0.254	\$ 0.223
125	\$ 0.382	\$ 0.279
150	\$ 0.383	\$ 0.335
175	\$ 0.445	\$ 0.390
200	\$ 0.509	\$ 0.446

Budget

Anticipated project cost were \$167,500 with NDIC grant allotment approved for 50% or up to \$83,810.

Proposed Budget:

Project Associated Expense	Total Cost	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Other Project Sponsor's Share
FEED Study FQPT	\$ 107,500.00	\$ 83,810.00	\$23,690.00		
FEED Study MMP	\$ 12,000.00				\$ 12,000.00
FEED DSA Engineering	\$ 2,720.00		\$ 2,720.00		
Barley Market Study	\$ 20,000.00		\$17,000.00		\$ 3,000.00
BPC Market Study	\$ 20,400.00		\$18,000.00		\$ 2,400.00
Regulatory	\$ 5,000.00		\$ 5,000.00		
Project Total	\$ 167,620.00	100%			
NDIC Total Request	\$ 83,810.00	50.0%			
Applicant Cash Total	\$ 66,410.00	39.6%			
Sponsor/Applicant In-kind Tot	\$ 17,400.00	10.4%			

Actual project costs totaled \$169,766.82 as of August 31, 2018.

ACTUAL					
Project Associated Expense	Total Cost	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Other Project Sponsor's Share
FEED Study FQPT	\$ 107,500.00	\$ 83,810.00	\$23,690.00		
FEED Study MMP	\$ 12,346.00				\$ 12,346.00
FEED DSA Support	\$ 4,431.80		\$ 4,431.80		
MAG Support Cash for Market & Reg	\$ 32,689.03		\$32,689.03		\$ -
Barley Market Study	\$ 12,000.00		\$ -		\$ 12,000.00
BPC Market Study	\$ 800.00		\$ -		\$ 800.00
Project Total	\$ 169,766.82	100%			
NDIC Total Request	\$ 83,810.00	49.4%			
Applicant Cash Total	\$ 60,810.82	35.8%			
Sponsor/Applicant In-kind Total	\$ 25,146.00	14.8%			

The most significant expenditure was the Feasibility Engineering Study completed by Fluid Quip. Summary describing the adequacy of the deliverables was provided earlier in this document and in appendices B and C.

Additional Considerations prior to Initiation of Project Phase 2

The phase 1 project scope has been completed with feasibility level studies identifying areas of challenge but no fatal flaw. In the phase 1 application we indicated: *upon satisfactory completion of objectives of phase 1 we intend to move forward with the second phase of the project which will include:*

1. *Detailed barley origination program development.*
2. *Detailed Engineering and Design completion.*
3. *Securing key marketing partners or offtake agreements for BPC and advanced biofuel.*
4. *Applying for/obtaining EPA RFS approvals and Low Carbon Market certifications*

However, based on learnings from this study we intend to perform additional analysis beyond feasibility level before moving on all aspects of Phase 2.

The capital expenditures necessary for integrating BPC project into an existing asset were higher than anticipated. The 30,240 ton per year plant identified as possible based on integration potential in this study will likely require additional debt/ financing to MAG. Understanding financing options and impacts of additional debt load to MAG has become necessary before continuing to Phase 2.

Alternatively the higher than expected capital costs may be addressed through decreasing the size and throughput of the plant below the volume range originally specified for this study. We intend to work with FQPT on determining capital costs of a smaller scale plant.

Internal modeling demonstrates the value for BPC in the marketplace is a critical driver to BPC viability. Aquaculture market expert analysis is required to fully comprehend the size, value, and intricacies of the fish meal substitute market and other protein feed markets. This expertise will bolster confidence in the projected financial return of a BPC project.

Dependent upon the results of the aforementioned items Phase 2 of the project may generally include:

1. Development of detailed barley origination program with grower contract options
2. Detailed Engineering and design completion
3. Secure offtake agreements or key marketing partner(s) for BPC with defined and indexed prices
4. Applying for/obtaining EPA RFS approvals and Low Carbon Market certifications
5. Completing Registration requirements for BPC into key International Markets

Barley Origination Study for Spiritwood, ND

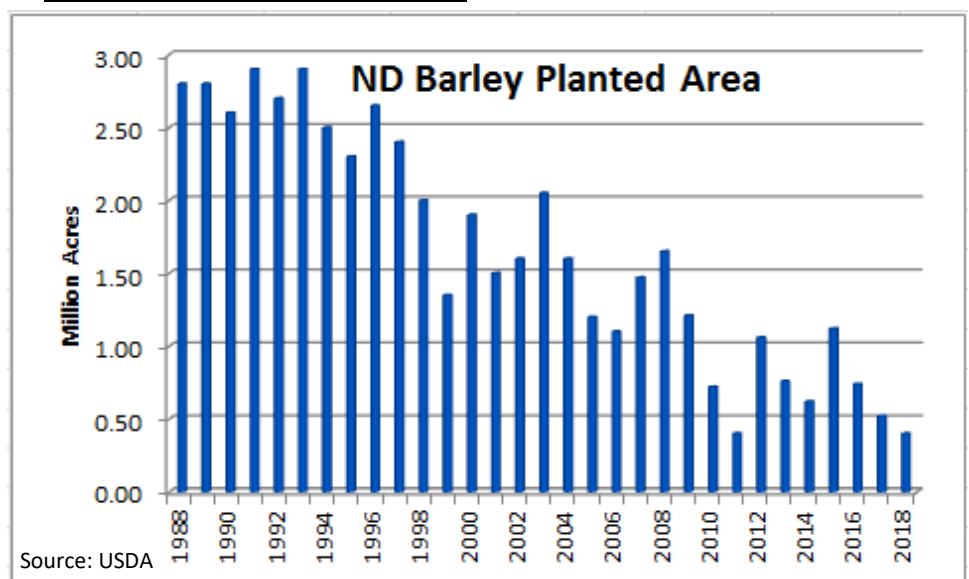
Barley Supply

North Dakota was the perennial leader in US barley production until 2011, when ND slipped to 3rd place in US barley production rankings. In the 2017-18 crop year, ND barley production totaled 25 million bushels. Last year's yield may have been adversely affected by dry weather, but ND's average yield was only 4 bushels/acre below the previous year. There has been a long-term decline in barley area in ND that has been responsible for the drop in barley production. Two leading factors in the decline in barley area have been climate and crop revenue. Environmental Protection Agency research¹ has shown that the average growing season for US crops has expanded 12 days on average since 1980. ND's climate has warmed more than the average of the 48 contiguous states; we could estimate ND's growing season has lengthened two weeks since

Crop Year	ND Production	
	M Bushels	ND Rank
1998	106	1
1999	60	1
2000	97	1
2001	80	1
2002	59	1
2003	119	1
2004	92	1
2005	57	1
2006	49	1
2007	78	1
2008	86	1
2009	79	1
2010	44	1
2011	16	3
2012	61	1
2013	46	2
2014	36	1
2015	67	1
2016	43	3
2017	25	3

1980. Barley and oats are the major cool season crops in ND. Both crops have diminished their area significantly in the last 20 years. The expansion of the growing season has allowed row crops such as corn and soybeans to expand. Those crops have created better cash flows than barley and have seen steady growth in area planted. (See page 5.)

A symptom of the fall in barley demand has been Cargill's announcement in April, 2018 that they will close their Spirit-



1. "Climate Change Indicators: Length of Growing Season" EPA. August 2016: <https://www.epa.gov/climate-indicators/climate-change-indicators-length-growing-season>.

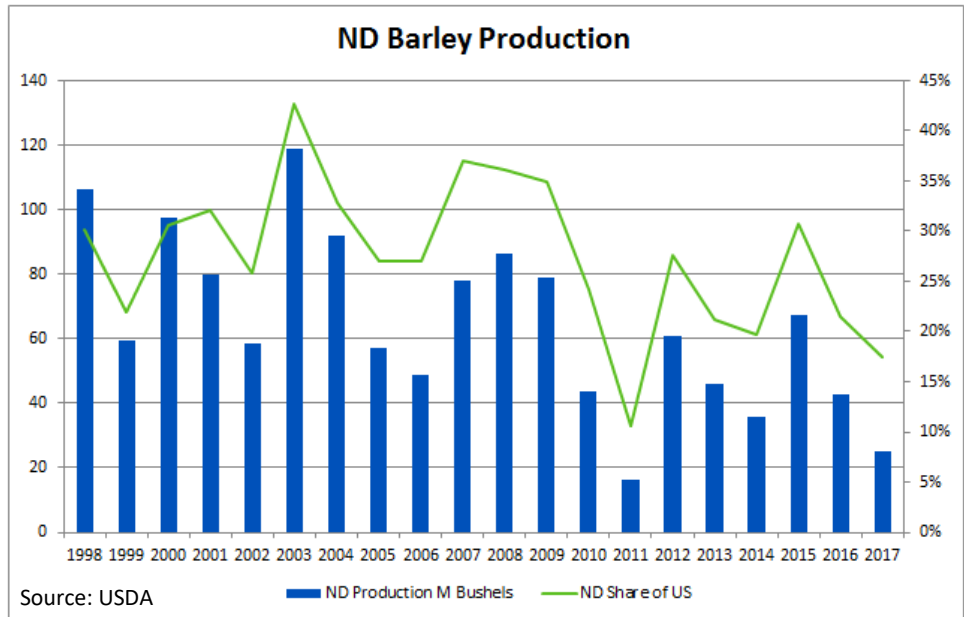
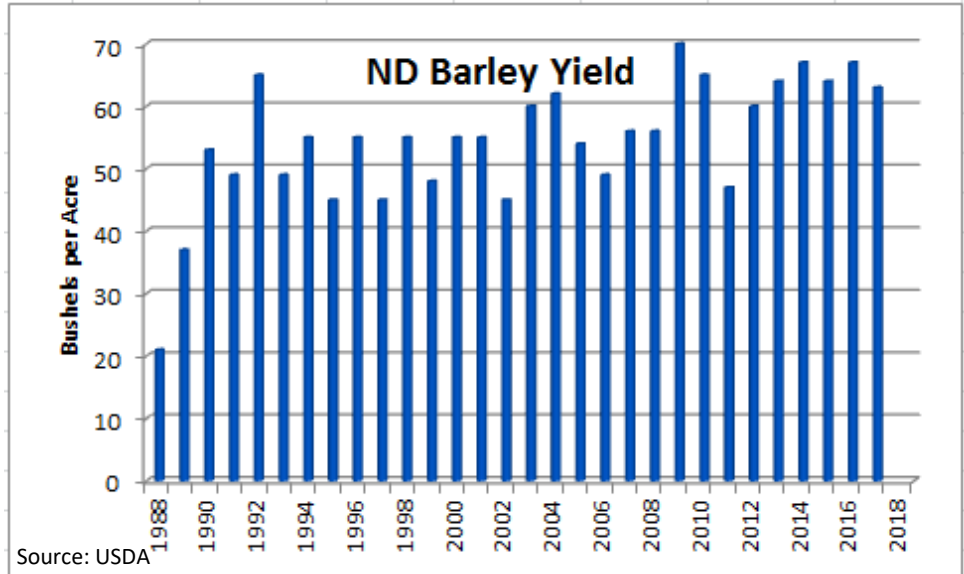
Barley Supply, Cont'd.

wood, ND barley malting plant after receiving the 2018 barley harvest. Barley production has shrunk to levels that should clear the marketplace of excess malting barley produced in the last three years. Previous malting barley contracts were offered at prices that attracted too much production during the commodity market downturn over the last three years. Malting barley contract offerings are lower this year, both in price and number of acres sought.

Barley yields have not moved much over the last decade. Some of this is due to the identity preserved nature of malting barley production. Maltsters like to stay with varieties with proven malting characteristics to maintain consistent performance in the consumer products. This slows the adoption of new varieties with potentially better yields.

Supply Summary

- ND barley planted area has shrunk to minimum levels while supply of malting barley remains surplus.
- Yields have been stable.
- Last year's planted area was the lowest in 30 years,



- except for one year of prevented plant due to weather conditions.
- Our project would consume 6.5 million bushels of barley, 25% of ND's 2017-18 crop.
- The exit of a significant buyer of barley this coming year

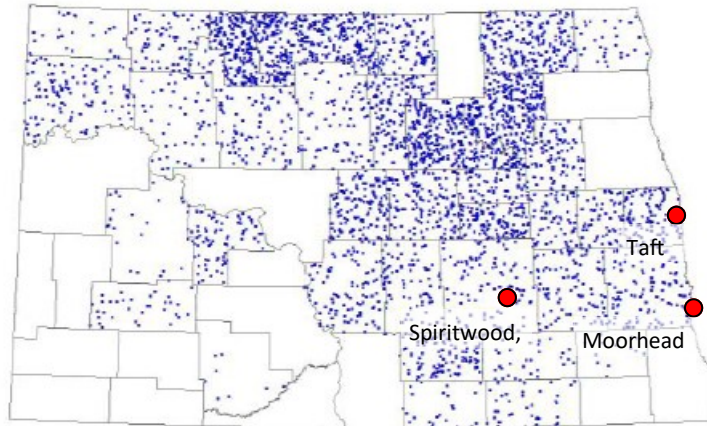
leaves an opening for a replacement buyer to enter the market with less price disruption than otherwise might be the case.

Barley Marketing and Pricing

Nearly all ND barley growers intend to raise malting barley when they plant the crop each spring. Whether they secure a contract to grow malting barley with a maltster or whether they plant without a contract, they are all aiming to capture the premium for malting grade. Malting companies reduce their supply risk by contracting acreage with a fixed price. When considering what price to offer, maltsters must offer a price that competes with farmers' cash flow from other cropping alternatives. This creates a partitioned market for malting barley vs. feed barley. The malting contract price offer reflects the price that garners the targeted acreage and production. Once the contracting period is done, the spot market for malting barley reflects the supply of malting barley vs. targeted supply. Barley that doesn't make malting specifications or is

Barley Production North Dakota: 2016

Malting Barley Buyer Locations Noted with Red Marker Dots



1 Dot = 10,000 Bushels

Dots randomly placed within county. Blank counties represent none harvested or undisclosed data.

Chart: USDA

Crop Year	Production M Bus	Ending Stocks	Implied Use	Stocks/Use %
1998	106.15	78.86	102.89	77%
1999	59.52	46.00	92.38	50%
2000	97.35	56.00	87.35	64%
2001	79.75	50.00	85.75	58%
2002	58.50	27.10	81.40	33%
2003	118.80	60.40	85.50	71%
2004	91.76	77.60	74.56	104%
2005	57.24	47.40	87.44	54%
2006	48.76	33.70	62.46	54%
2007	77.84	33.60	77.94	43%
2008	86.24	60.00	59.84	100%
2009	79.10	89.23	49.87	179%
2010	43.55	64.66	68.12	95%
2011	16.45	22.04	59.07	37%
2012	60.60	57.44	25.21	228%
2013	46.08	53.28	50.24	106%
2014	35.85	52.77	36.36	145%
2015	67.20	74.68	45.29	165%
2016	42.88	64.76	52.80	123%
2017	24.89			

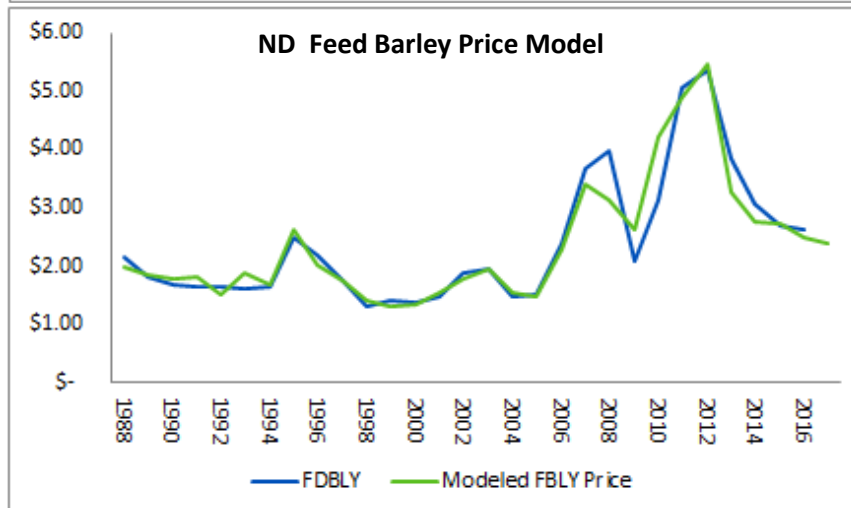
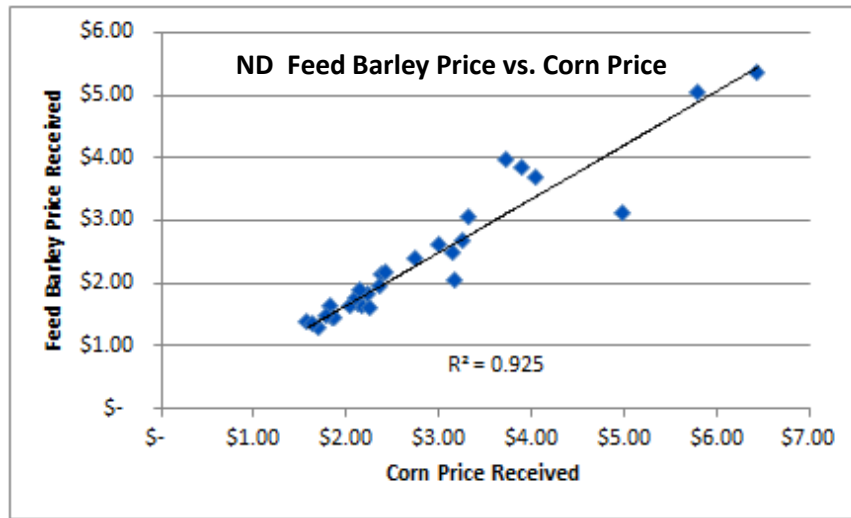
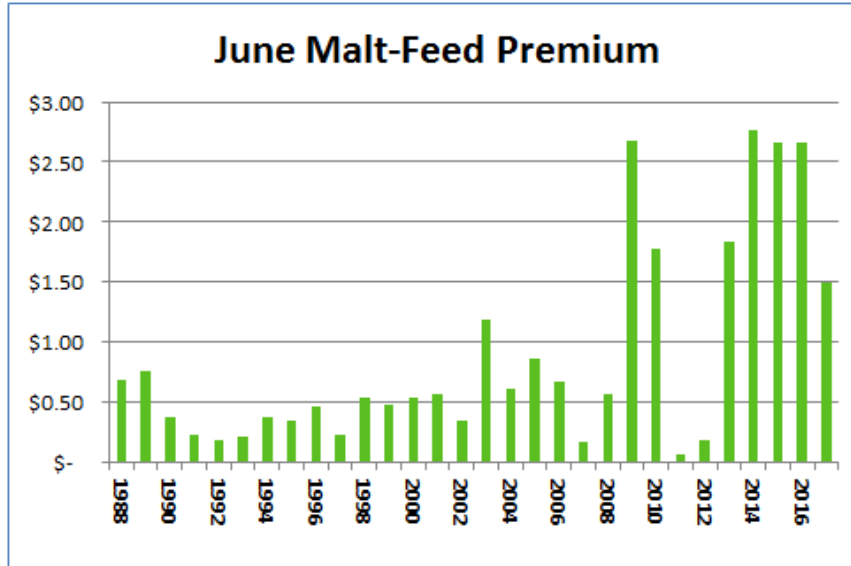
grown without a contract may have to be sold as feed. In the last five years barley production has exceeded use. This is a result of good production, stagnant malting demand and falling feed use in ND. When malting barley floods the market, the excess needs to force itself into the feed market. This has resulted in heavy discounts for feed quality barley compared to malting barley contract prices. The top chart on the following page shows the average price premium for malting barley over feed barley over the last twenty years during the month of June. This is an arbitrary measure of the relative value of malt vs. feed. Comparisons taken at different points in time may show different relative values. When considering what price Midwest AgEn-

Barley Marketing and Pricing

ergy may need to pay for barley, we assume we will need to offer a similar price as malt contracts to entice farmers to plant the crop.

Price Analysis

We have isolated the feed price of barley vs. the price of corn, then tracked the relative value of malting barley vs. feed barley. The price of feed barley has a strong correlation with the price of corn paid to ND farmers. This makes sense, for they are both priced for their nutritional value in livestock rations. We have constructed a price model that does a good job of predicting feed barley prices using ND corn prices paid to farmers. Using the CBOT corn futures market forward curve and



applying our corn basis estimates, we can project a fair price for feed barley for nearby and future delivery periods. Estimating the price farmers will be offered for malting barley is a less certain endeavor. Maltsters don't generally publicize their contract prices before and during the contracting process. We can estimate a competitive barley contract price by constructing a cash flow comparison of malt barley vs. other cropping alternatives.

This table shows projected cash flows for East Central North Dakota farmers enrolled in the NDSU Extension Farm Management program.

Barley Marketing and Pricing

This is a summary of estimated revenue, cost and margins based on their actual costs and yields. Revenue is based on prices available in early April 2018. Barley prices are the malting barley contract prices on offer at that time. NDSU projected the feed barley price at \$2.70 compared to the \$3.46 malting contract. Barley returns ranked well below expected returns on soybeans, wheat and corn. Wheat would be considered the chief competitor for barley. Both grains occupy the same place in standard crop rotations between corn, soybeans and small grains. In order for barley returns to match spring wheat returns, the barley price would need to be \$0.69/bushel higher—or the barley yield would need to be 14 bushels/acre higher. We mention yield as a variable because there may be changes in cultivation practices that raise barley yield for the product we specify. Malting barley specs usually limit the maximum protein level of 13.5%. Barley yield responds to nitrogen fertilizer; protein content also responds

to nitrogen. It is likely that barley farmers would increase their nitrogen application to maximize

Crop	Mkt Rev. per Acre	Dir. Costs per Acre	Ret. Over Dir. Costs	Over Price
Mustard	\$ 263.50	\$ 101.90	\$ 161.60	\$ 0.310
Soybeans	\$ 292.05	\$ 153.06	\$ 138.99	\$ 8.850
HRSW	\$ 308.34	\$ 177.14	\$ 131.20	\$ 5.710
Drybeans	\$ 362.25	\$ 232.17	\$ 130.08	\$ 0.225
Durum	\$ 301.92	\$ 176.94	\$ 124.98	\$ 6.290
Corn	\$ 406.25	\$ 288.31	\$ 117.94	\$ 3.250
Oil_SF	\$ 268.32	\$ 168.20	\$ 100.12	\$ 0.172
Conf. SF	\$ 296.70	\$ 197.80	\$ 98.90	\$ 0.230
Rye	\$ 216.20	\$ 123.11	\$ 93.09	\$ 4.600
Buckwht	\$ 184.30	\$ 95.95	\$ 88.35	\$ 0.194
Barley	\$ 235.28	\$ 150.82	\$ 84.46	\$ 3.460
Canola	\$ 278.73	\$ 197.50	\$ 81.23	\$ 0.171
Peas	\$ 220.50	\$ 144.72	\$ 75.78	\$ 6.300
Flax	\$ 172.98	\$ 100.82	\$ 72.16	\$ 9.610
Wint.Wht	\$ 232.67	\$ 162.46	\$ 70.21	\$ 4.390
Millet	\$ 110.50	\$ 70.61	\$ 39.89	\$ 0.065
Oats	\$ 147.75	\$ 114.22	\$ 33.53	\$ 1.970

Source: NDSU Extension Farm Management Program.

yield without the threat of rejection on account of excess protein. At today's nitrogen and barley prices it would take approximately 4 bushels of barley to "buy" fertility for 35 bushels more yield. That should be sufficient incentive for growers to push for higher yields. The 31 net bushel per acre gain would be worth \$107/acre in added margin which is more than enough to favor barley produc-

tion over wheat.

If our assumption about yield enhancement is correct we may not need to offer as much price premium as maltsters to garner acreage that we require. Farmers may need to do their own experimentation with enhanced yields before embracing a bid that depends on them getting higher productivity. There is research that shows higher yields are available with more intense management. We expect farmers would adopt those practices over time.

Spot Market Strategy

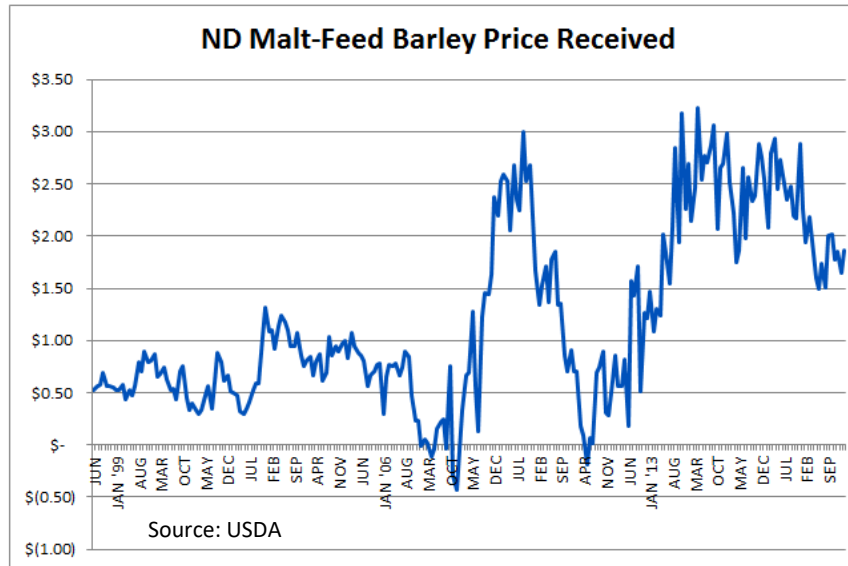
Beside offering pre-planting contracts for barley, we may also plan to utilize the barley spot market for a portion of our supply. The top chart on page 6 tracks the monthly spread in prices received for malting and feed barley types. In years with high ending stock/use ratios (above 100%) the price of feed barley fell to its widest discount to malting barley. There are pitfalls to comparing these prices over time. First, malting barley contracts are usually set in the

Barley Marketing and Pricing

winter months prior to planting. Those prices are fixed for the crop year. Prices for feed barley fluctuate with the spot market for corn and other feed grains. Comparing a fixed malting price to a floating feed price can be misleading. However, as long as feed barley prices have such a strong relationship with corn prices, we are able to use the CBOT corn futures market to set the expected feed barley price and lock in the fixed relationship between feed barley price and malting barley price. This gives us flexibility to vary the amount of barley we contract in advance if we see strategic reasons to increase or decrease our exposure to the fixed price contracts. Another factor in deciding to stay uncontracted on some barley supply is the possibility we may

purchase rejected malt barley at feed prices. Barley quality is affected by weather. Protein con-

discounted price. Barley quality varies from year to year and is difficult to predict in advance.

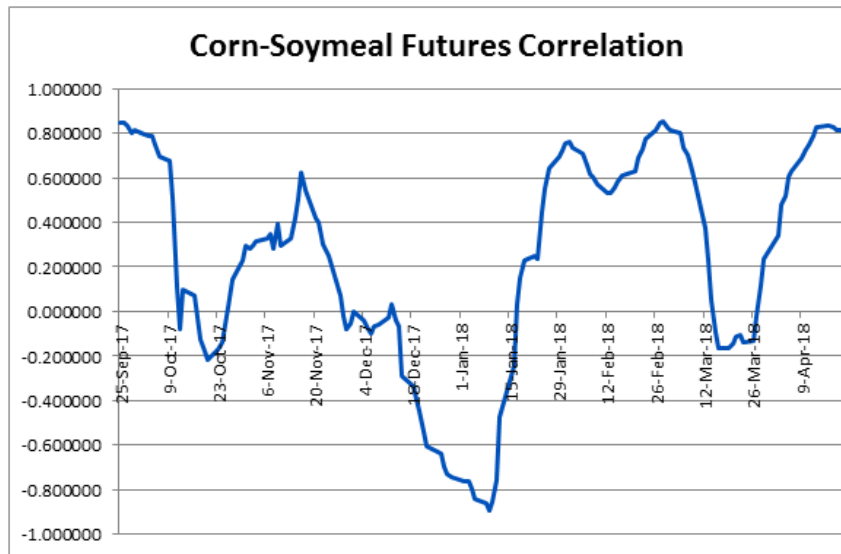


Price Correlations

Ultimately we are converting a feed grain into a protein product. There are no price precedents for the barley protein product we will be producing. We have nominated corn futures and soymeal futures

tent, seed coat color and kernel plumpness are all factors that may disqualify barley for malting, yet may be tolerable to us at a

as proxies for the two commodities we will handle. The bottom chart on page 6 shows the 20-day smoothed correlation between the spot corn futures



contract and the spot soymeal futures contract. There is not a stable correlation between the two markets. In fact it appears that correlations swing from strong positive to strong inverse correlations. This implies we should

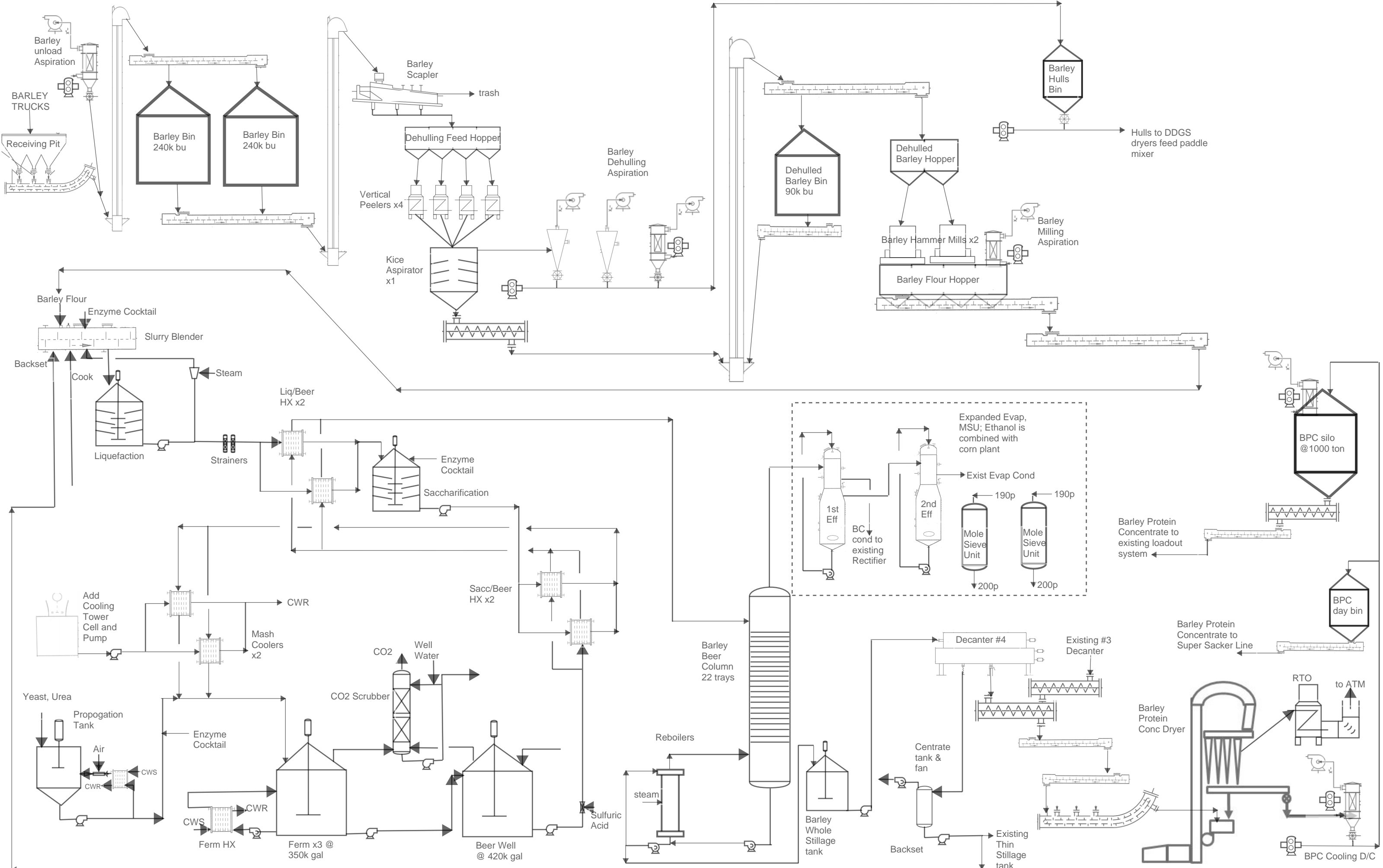
Barley Marketing and Pricing

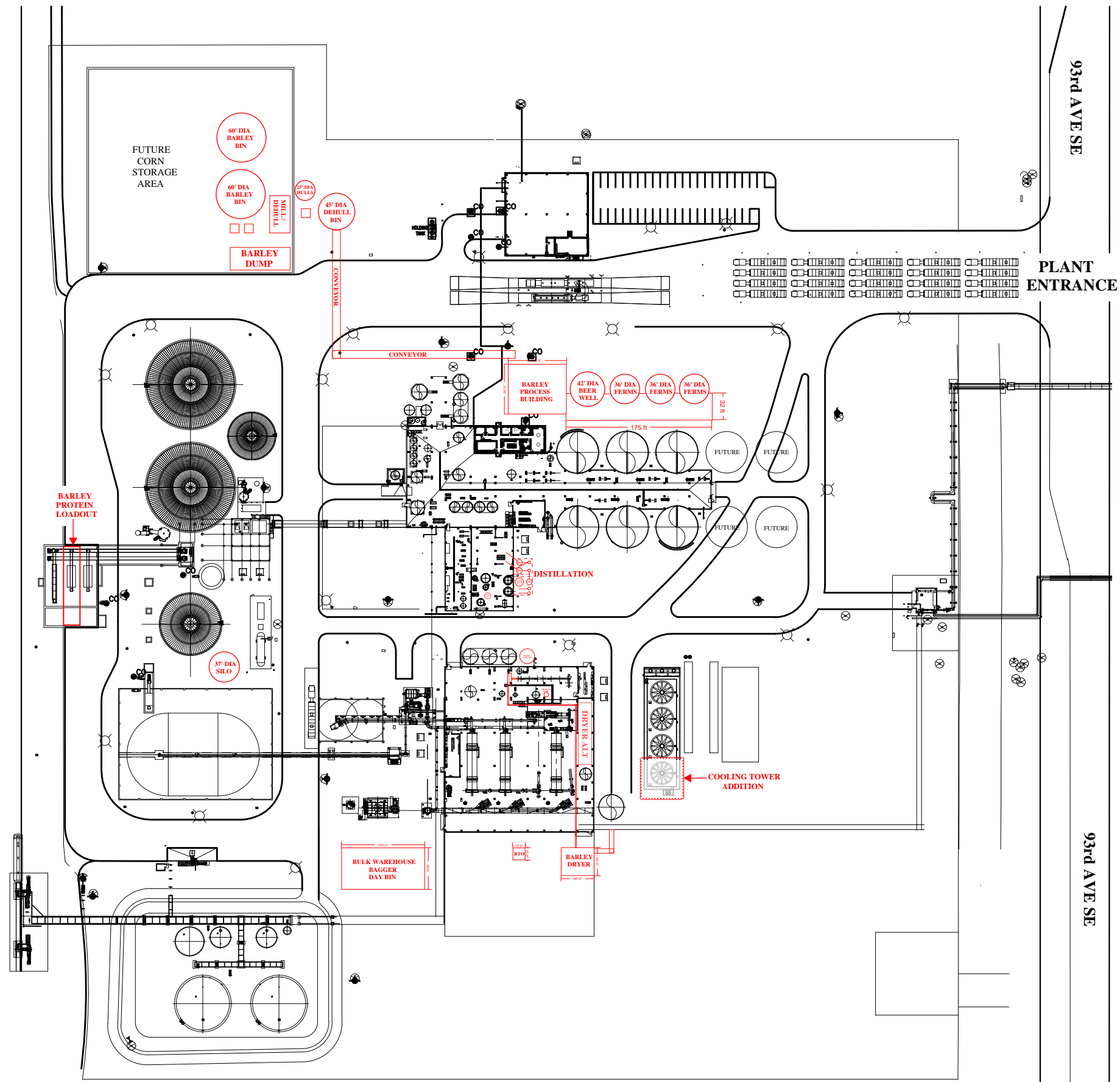
manage price risk of the two commodities separately and not mix our barley hedging with our protein hedging unless/until it is part of a strategy to capture the crush margin between the two.

Marketing Summary

- Procuring barley supply will put us in competition with malting barley buyers in ND.
- Historic abandonment of barley culture has been in response to stagnant demand from maltsters. As recently as ten years ago, ND barley area was over 1.5 million acres, compared to 0.4 million acres in 2017. Our project envisions demand for production from 75,000 acres. There should be ample room for us to enter the ND barley market alongside existing malting demand.
- Determining a contract price to offer growers will require us to bid the price that gives farmers a competitive cash flow with other crops, primarily spring wheat.
- Market conditions over the last three years suggest we can offer a competitive cash flow cropping option while maintaining a feedstock cost low enough to achieve satisfactory processing margins.
- Higher carryover stocks of barley tend to depress the price of spot barley and widen the premium of malting barley over feed quality. We must monitor the ND barley supply/demand balance to help anticipate the spread between feed quality and malting quality barley year-over-year.
- Feed barley prices are correlated with corn prices in ND. This means corn futures may be used to fix prices, or to unfix prices of barley when necessary.
- Due to differences in specifications for our barley (protein content), farmers may see an agronomic opportunity to maximize yields and lower their cost of production by contracting with MAG.
- We may specify varieties and promote production practices that exclude our product from the market for malting barley. That will shelter our market from large price swings in malting barley within a crop year.
- There is only intermittent correlation between feed grain and protein meal prices. We will need to segregate our risk management activities between those markets

We are grateful to the ND Barley Council and Exec. Director Steve Edwardson for supplying crop data and background on ND's barley growers and malting industry.





93rd AVE SE

PLANT ENTRANCE

93rd AVE SE

Barley Protein Concentrate in Aquaculture

The need to feed the world's growing population is a much discussed and well documented issue that faces our future. Growing prosperity among the world's developing economies is increasing food consumption per capita, in addition to the growing population numbers. The World Health Organization finds that "(t)here is a strong positive relationship between the level of income and the consumption of animal protein, with the consumption of meat, milk and eggs increasing at the expense of staple foods." They project that average daily per capita caloric consumption will increase 9% from 1999 to 2030.¹ During the period from 1999 to 2030, world population is expected to increase from 6.06 billion people to 8.55 billion.² Combining the estimated population increase and the higher per capita food consumption, we can project demand for food to grow ap-

proximately 1.5% per year while world population grows at 1.2% per year.

Food Production Efficiency

The finite supply of arable land and fresh water are beginning to be felt as we put ever more stress on our terrestrial resources. Step changes in grain production have begun to moderate as incorporation of genetically modified organisms has approached saturation. USDA estimates that 92% of US corn area and 94% of US soybean area were planted with GMO seed in 2018. Food crops, including wheat do not allow GMO seed use due to consumers' lack of acceptance. Livestock husbandry also faces challenges as resources become more scarce. Cattle fed grain diets require 6-7 pounds of feed to produce 1 pound of meat. Swine fed grain diets need 2.5 pounds of feed to produce one pound of meat. The feed conversion ratio (FCR) of poultry is much better at 1.25

pounds of feed to 1 pound of meat.

In addition, the water to grow grains is becoming a hot-button issue. In some states, water for crop irrigation is at odds with drinking water supply for cities. The US Geological Survey estimated³ that in 2015, irrigation uses consumed 42% of US water supply. California consumed 9% of the national water supply by itself. California's irrigation use amounted to 2/3 of the state's total consumption. Texas water consumption placed second to California at 7% of national use. Irrigation use of water in the US was 3 times the public water supplied for human consumption. Recent drought conditions in the Western US have fueled increased controversy over US' long term water use priorities.

Fish Protein

Fish are the most efficient converters of feed to protein. Salmon and catfish in aquacul-

1. World Health Organization, Nutrition Health Topics, http://www.who.int/nutrition/topics/3_foodconsumption/en/index1.html
2. UN Dept. of Economic and Social Affairs, *World Population Prospects: The 2017 Revision, Medium Variant Case*.
3. USGS, *Water Use in the United States*, <https://water.usgs.gov/watuse/wuto.html>

ture settings approach 1:1 Feed Conversion Ratio. Fish protein is a healthy alternative to red meat, with lower levels of fat, saturated fat and cholesterol. Species such as Salmon are a leading source of heart healthy omega 3 fatty acids which help to lower low density lipid (“bad” cholesterol) levels in humans.

Supply of Fish Protein

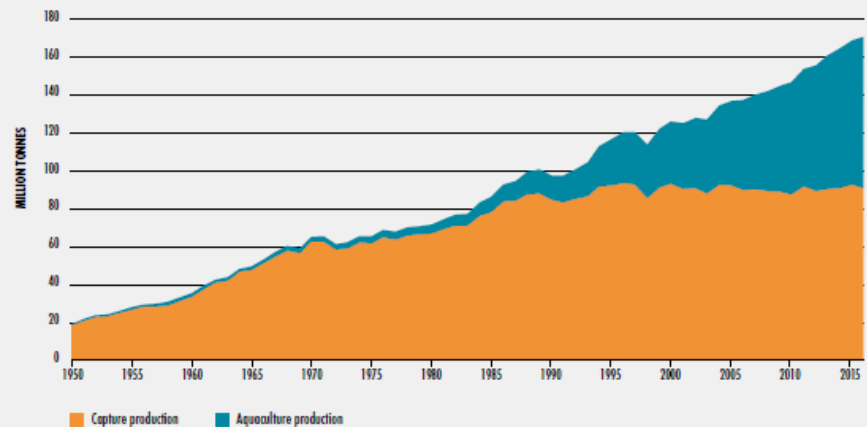
According to the United Nations Food and Agriculture Organization, the supply of wild-

"Since 1961 the annual global growth in fish consumption has been twice as high as population growth, demonstrating that the fisheries and aquaculture sector is crucial in meeting FAO’s goal of a world without hunger and malnutrition"

José Graziano da Silva, FAO Director-General

caught fish is peaking. The adjoining chart shows the plateau in supplies of fish captured from the wild. Since the mid-1980’s fish capture has held almost steady in the world. Better technology for catching fish has triggered government regulation of fisheries to check the alarming rate of decline in wild fish numbers. “The fraction of fish

**FIGURE 1
WORLD CAPTURE FISHERIES AND AQUACULTURE PRODUCTION**



NOTE: Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants

Source: UN/FAO

WORLD FISHERIES AND AQUACULTURE PRODUCTION AND UTILIZATION (MILLION TONNES)^a

Category	2011	2012	2013	2014	2015	2016
Production						
Capture						
Inland	10.7	11.2	11.2	11.3	11.4	11.6
Marine	81.5	78.4	79.4	79.9	81.2	79.3
Total capture	92.2	89.5	90.6	91.2	92.7	90.9
Aquaculture						
Inland	38.6	42.0	44.8	46.9	48.6	51.4
Marine	23.2	24.4	25.4	26.8	27.5	28.7
Total aquaculture	61.8	66.4	70.2	73.7	76.1	80.0
Total world fisheries and aquaculture	154.0	156.0	160.7	164.9	168.7	170.9
Utilization^b						
Human consumption	130.0	136.4	140.1	144.8	148.4	151.2
Non-food uses	24.0	19.6	20.6	20.0	20.3	19.7
Population (billions) ^c	7.0	7.1	7.2	7.3	7.3	7.4
Per capita apparent consumption (kg)	18.5	19.2	19.5	19.9	20.2	20.3

^a Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants.

^b Utilization data for 2014–2016 are provisional estimates.

^c Source of population figures: UN, 2015e.

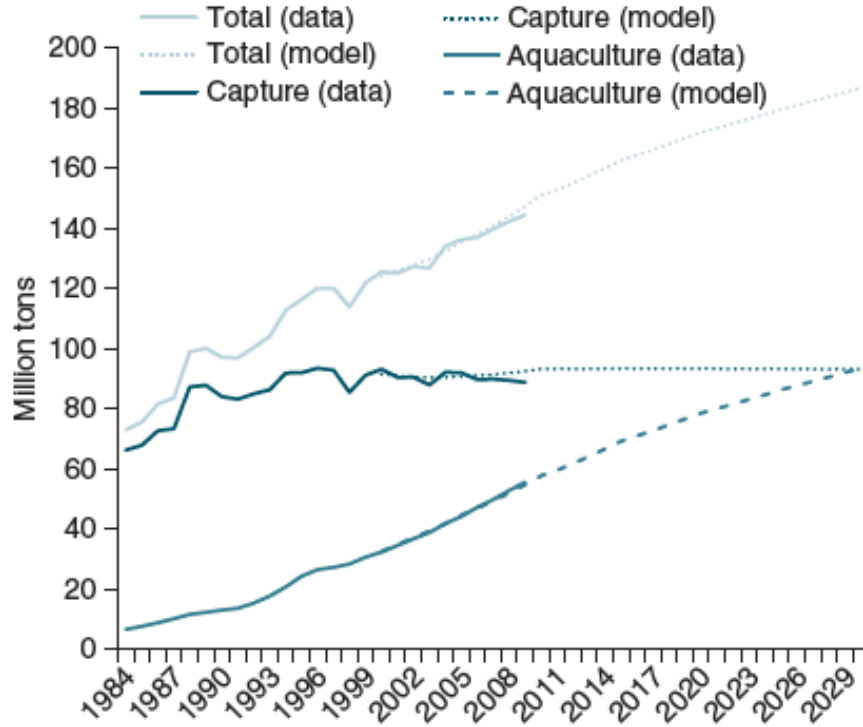
stocks that are within biologically sustainable levels has exhibited a decreasing trend, from 90.0 percent in 1974 to 66.9 percent in 2015. In contrast, the percentage of stocks fished at biologically unsustainable levels increased from 10 percent in 1974 to 33.1 per-

cent in 2015, with the largest increases in the late 1970s and 1980s.”⁴ All of the increase in fish food supplies since the mid-1980’s has been attributable to the rise of farmed fish-aquaculture. Aquaculture fish production has grown at a compounded

4. United Nations FAO: 2018, *The State of the World’s Fisheries and Aquaculture*

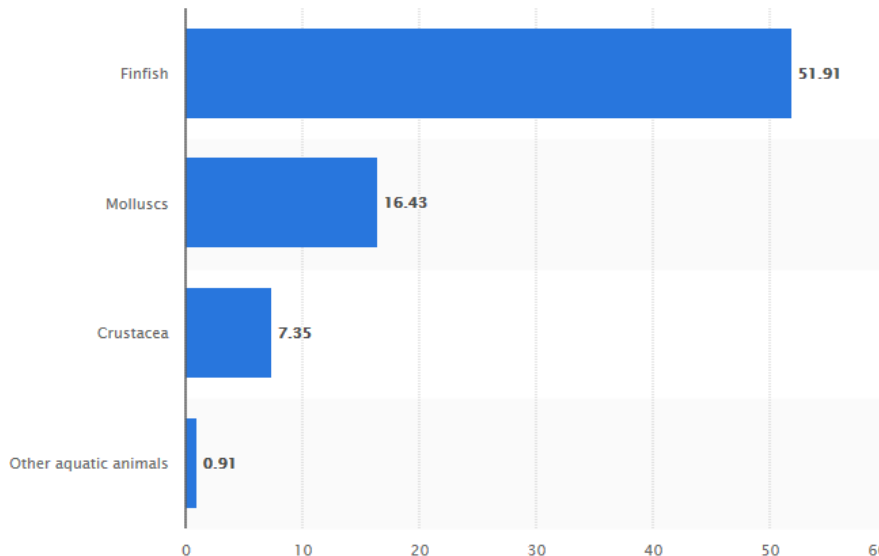
rate of 3% per year from 1985. Farmed fish supplied 48% of all fish consumption in 2015, according to FAO.

Aquaculture promises to be a vital solution for supplying high quality protein to a growing world, with the highest economic efficiency and the least impact on our wild fish populations. Additionally, most marine aquaculture does not consume water resources as terrestrial animals do. Typical cultural practices are sited in existing coastal waters. Much of freshwater aquaculture is built as flow through raceways in streams and rivers. Freshwater ponds are increasingly regulated to require closed systems with monitoring for environmental impacts. Looking forward, the World



Sources: FishStat and IMPACT model projections.

Leading Species in Aquaculture Production, 2015



Bank sees total fish production rising from 170.9 Mmt in 2016 to 186.3 Mmt in 2030. Farmed

fish supply will grow 13.6 Mmt while wild caught supply is expected to grow only 2.3 Mmt.⁵ There are 3 major classes of aquaculture production, finfish, mollusks and crustaceans. Within these classes there are several ways of classification. We are most interested in the carnivorous (piscivorous) finfish such as salmon and trout, both members of the salmonid family. Salmonids are estimated to comprise 3.06 Mmt (5.7%) of annual world finfish aquaculture output.⁶ Salmon and trout need high quality diets, which have typically contained 35-45% fish meal until just recently.

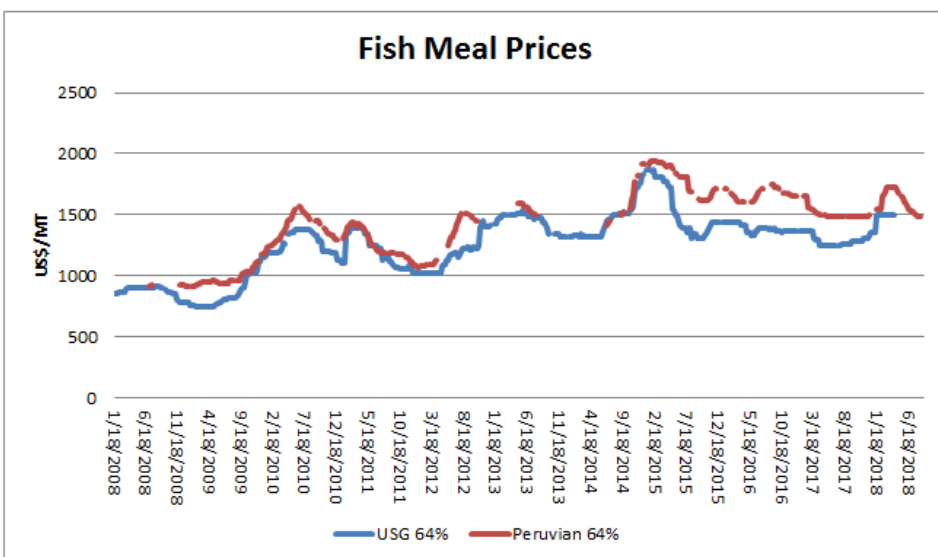
5. The World Bank: December 2013, *Fish to 2030, Prospects for Fisheries and Aquaculture*. Report number 83177-GLB.

Commercial aquaculture diets for salmonids rely on fish meal as the major protein source. Fish meal is manufactured from so-called “trash fish” which are fish that occur in high numbers but have little directly extractable nutritional value for humans. Other sources of raw material for fish meal are entrails from pro-

cessing plants that produce fish for human consumption. Fish meal is made by netting these trash fish and dehydrating them into fish meal and fish (FAO) estimates that the ratio of fishmeal output to whole fish input is 23%.⁵ That means it takes a little over 4 kilograms of whole fish to make 1 kilogram of fish meal. Small fish that supply the fish meal market are wild-caught

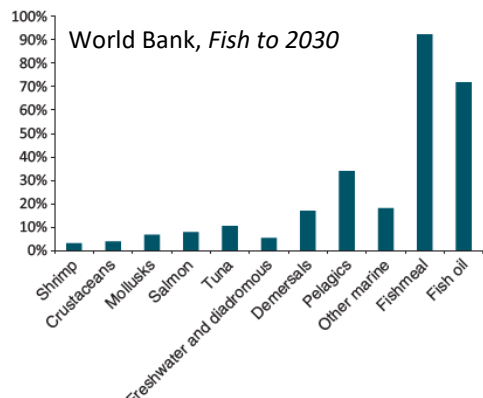
and now face the same over-fishing threats the species caught for human consumption face. The peak in whole fish supply for fish meal came in 1994 when 30 Mmt of fish were processed into meal. In 2016 that volume had declined to 15 Mmt. FAO estimated worldwide fish meal production in 2016 at 4.45 Mmt. As avail-

The World Bank report on Fish to 2030 models a price increase of 90% in real terms between 2010 and 2030. A rough calculation based on a 2010 price of \$1,300/mt would put fish meal prices at \$2,500/mt before inflation adjustment. This creates an incentive to find alternatives to fish meal that can be substituted for fish meal in aquaculture diets. The requirements for substitute feeds are that they are nutritionally balanced, palatable, water stable and, of course, economical compared to fish meal. Researchers are studying many potential supply sources such as vegetable, insect, algae, milk and terrestrial animal protein. This is in addition to grains and oilseed meals that are currently included as carbohydrate sources in aquacul-



ability of fish meal declined prices have increased. The outlook for the future is for stable harvests of small pelagic fish that supply the fish meal market. Countries are placing quotas on the annual “trash fish” catch to shield the ocean’s resources from complete depletion. With farmed fish production expected to grow nearly 14 Mmt by 2030, the pressure on fish meal supply will be felt in higher prices.

FIGURE 3.6: Projected Change in Real Prices between 2010 and 2030 by Commodities



Commodity	Projected Change (%)
Shrimp	~2%
Crustaceans	~5%
Mollusks	~8%
Salmon	~10%
Tuna	~12%
Freshwater and diadromous	~15%
Demersals	~18%
Pelagics	~35%
Other marine	~18%
Fishmeal	~90%
Fish oil	~70%

Source: IMPACT model projections.

6. FAO: 2018, *The State of World Fisheries and Aquaculture*.

ture diets. Most of the substitutes have disadvantages, whether it be physical properties, anti-nutritional factors, or palatability. The chart at right indicates barley (grain) is well digested but has some amino acid imbalances and is high in fiber. Our Barley Protein Concentrate eliminates most of the disadvantages during the processing stage and creates one of the most palatable and digestible protein high protein substitutes available today. The largest commercial trout farm in the US has done commercial trials with our product and is convinced that BPC can be substituted for fish meal up to 30% of total diet inclusion, with minimal or no supplementation.

Dedicated research done by RAFOA (Research on Alternatives to fish Oil in Aquaculture at the University of Scotland) and PEPPA (Perspectives of Plant Protein Use in Aquaculture coordinated by the French National Institute for Agricultural Research) suggest that alternative protein sources may replace 20 to 25 percentage points of fish meal in salmonid rations. To estimate the potential for fish meal potential in annual volume, we first must take stock of current fish meal consumption for the

2009, From *FAO Fisheries and Aquaculture Technical Paper #541*

TABLE 30
Advantages and disadvantages of some of the plant substitutes for fishmeal

Plant substitute	Advantages	Disadvantages
Soybean meal (SBM)	Economical and nutritious with high crude protein (44–48%) Cystine in higher concentration	Concentrations of the 10 essential amino acids (EAA) (lysine, methionine, cystine and threonine may be limiting) and tyrosine are lower; crude fat and ash content is lower but can be overcome with supplementation; high in non-starch polysaccharides; reduced feed intake; growth and development of intestinal enteritis; presence of anti-nutritional factors such as lectin; low in available phosphorous
Soybean protein concentrate (SPC)	EAA concentration matches or more to EAA concentrations in fishmeal	Methionine, cystine may be limiting; not economical for large scale use; crude fat and ash content is lower but can be overcome with supplementation
Soy protein isolate (SPI)	EAA concentration matches or more to EAA concentrations in fishmeal	Methionine, cystine may be limiting; not economical for large-scale use; crude fat and ash content is lower but can be overcome with supplementation
Canola meal	Not widely used in aquafeeds, similar to the protein content of SBM	The price similar to that of SBM; low in available phosphorous
Canola protein concentrate	Protein content similar to high-quality fish fishmeal, widely tested as a protein source for salmonids and other carnivorous species of farmed fish, supports growth rates similar to those of fish fed fishmeal-based diets	Amino acid supplements needed to overcome limiting amino acid levels; feeding stimulants are needed to overcome reduced feed intake
Corn gluten meal	Crude protein content of 60–73%; corn gluten meal is currently widely used in aquafeeds for salmon and several marine species such as European seabass and gilthead seabream; highly digestible	Limited in commercial production; deficient in EAA lysine
Corn distillers dried grains with solubles (DDGS)	28–32% crude protein	High in fibre content
Cottonseed meal	10 and 30% of solvent extracted; 40% protein CSM can be used in aquaculture diets without growth depression	Presence of gossypol may have toxic effects
Peas/lupins	High protein apparent digestibility coefficient	Lysine and methionine are limited; high levels of carbohydrate (fish do not metabolize non-starch polysaccharides in lupins); presence of anti-nutrient quinolizidine alkaloids; lysine is limiting
Wheat	Low in protein (<11)	Wheat is primarily an energy source based on its high starch composition (typically >70%); lysine is limiting
Barley	Barley protein is well digested	Low crude protein content (9–15%); high in fibre; low in available phosphorous; lysine and arginine may be limiting; high in fibre

Source: Gatlin et al. (2007).

Targeted reduction of dependency on fishmeal and oil

Species	Current inclusion (%)		Targeted inclusion (%)	
	Fishmeal	Fish oil	Fishmeal	Fish oil
Atlantic salmon	35–47	25–33	12–16	8–12
Rainbow trout	30–35	20–25	5	5
Seabream	40–45	15–20	15	10
Common carp	20–25	5–10	0	0

Source: RAFOA and PEPPA (personal communication).

salmonids. In 2008 Albert Tacon and Marc Metian published an article titled “Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects.”⁷ They estimated that in 2007 global commercial feed produced for salmon was be-

tween 1.77 Mmt and 1.94 Mmt and that the average ration inclusion rate for fish meal was 30%. They estimated global trout commercial feed production was between 0.554 and 0.586 Mmt with fish meal averaging 30% of the ration weight. The table below summarizes the global potential to substitute alternative proteins for fish

meal. This incorporates the fish meal substitution targets developed by RAFFOA and PEPPA. This places the potential demand for Barley Protein Product between 390,000 mt and 500,000 mt as of 2007. It's likely salmonid aquaculture feed production has grown 40% since 2007 which would inflate the potential ranges to 546,000 mt to 700,000 mt today. If we assume salmonid aquaculture maintains its 7% share of global aquaculture production, the 13.6 Mmt growth in total finfish production would include 952,000 mt of grow in salmonid production, which would increase

salmonid market demand for BPC could reach 800,000 tons by 2030. Dr. Frederick Barrows, a leading researcher in aquaculture nutrition, tells us that BPC could potentially replace up to 20% of any fish diet depending on price relationships. Other species of fish use high rates of fish meal in their diets. World consumption of commercial feed for shrimp is near 4 Mmt annually with 20% of that diet estimated to be fish meal. During stages of their life cycle diet, BPC could be a valuable substitute for fish meal. Other species of fish such as yellowtail and red sea bream have also been fed fish

farmed fish production of these two species had declined 10% from 2006, generally due to declining production margins as a result of high feed (fish meal) costs.

If we projected that BPC could replace 10% of the 0.8 Mmt of fish meal fed to shrimp we could add another 80,000 tons of potential demand for BPC today. If BPC penetrated the Japanese aquaculture diet for yellowtail and red sea bream it could add another 20-30,000 tons of demand for BPC. Adding current estimates of salmonid demand for BPC we see the following addressable market for BPC:

Salmonids: 550,000
 Shrimp: 80,000
 Japanese Piscivores: 20,000

World Demand (mt) 650,000

Our initial marketing efforts will be domestic US demand. US commercial feeding of trout is the largest finfish source of fish meal demand. The commercial trout farm that is willing to commit to feeding our product assures us that BPC has equal value to them as Class II fish meal. From U.S. Department of Agriculture Economic Research Service trout inventory statistics, we estimate

	Total Ration		Fish Meal Fed MMT	Target Fish Meal %	Target Fish	Fish Meal
	MMT	Fish Meal %			Meal Fed	Substituted
Salmon						
Low Estimate	1.77	30%	0.53	16%	0.2832	0.25
High Estimate	1.94	30%	0.58	12%	0.2328	0.35
Trout						
Low Estimate	0.554	30%	0.17	0.05	0.0277	0.14
High Estimate	0.586	30%	0.18	0.05	0.0293	0.15
Salmon + Trout						
Low Estimate	2.324	30%	0.70	13%	0.3109	0.39
High Estimate	2.526	30%	0.76	10%	0.2621	0.50

commercial feed by about 1 Mmt per year by 2030. Assuming substitutes displace 10% of that feed increase, the

meal in similar proportions as salmonids. Japan's demand for fish meal in yellowtail and sea bream was estimated at 75,000 tons in 2006.⁸ In 2012

7. Tacon and Metian, 2008, *Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects*. Aquaculture Issue 285 , pp. 146-158.

8. Ibid.

aquaculture commercial feed demand at 39,000 tons in the US. Potential replacement of fish meal in trout diets at 25% inclusion would yield 9,750 tons of demand of BPC. US finfish aquaculture is heavily concentrated in catfish production. US producers feed approximately 750,000 tons of commercial feed to catfish, but diets contain only about 5% fish meal.⁹ That would present potential sales potential of 35,000 of BPC to replace fish meal.

Shrimp farming in the US consumed 7,000 tons of fish meal in 2006, which could be replaced by BPC.¹⁰

We see current potential US sales volume near 50,000 tons of BPC.

Our next door neighbor Canada has a very significant marine aquaculture industry. British Columbia produced 93,000 mt of salmon and trout as of 2016.¹¹ This market could potentially consume 25,000 tons of BPC and is easily accessible logistically for our product.

Our initial business model indicates our BPC product would cost just over \$12.00 per ton per percentage of protein to produce and transport to the Pacific Northwest, with barley input cost of \$175/ton. Prices for Class II fish

meal in Western US markets are above \$23.00 per ton per unit of protein today.

Summary

- World demand for commercially farmed finfish is rising and will soon equal the wild caught harvest.
- All future net growth in finfish production will come from farmed fish.
- Fish meal supply has peaked and will not be able to match growth in aquaculture feed demand.
- BPC is one of the most compatible protein feeds available for piscivores like salmon, trout and tuna.
- Potential world demand for BPC is 650,000 tons and could grow 3-4% per year with anticipated growth in aquaculture production.
- BPC production costs allow profitable margin opportunities vs. current fish meal prices.
- World bank estimates that fish meal supply restrictions may cause prices to rise 90% in the next decade.

9. Tacon and Metian, 2008, *Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects*. Aquaculture Issue 285, pp. 146-158.

10. Ibid.

11. Government of Canada, *2016 Canada Aquaculture Statistics*, <http://www.dfo-mpo.gc.ca/stats/aqua/aqua16-eng.htm>