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Initial Assessment of the Agricultural Risk of Temporary Water Storage for FM Diversion

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NDSU NORTH DAKOTA STATE UNIVERSITY

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Preface

A project as large as the FM Diversion has the potential to affect many different constituents. Various elements of the Diversion have been discussed, studied, and debated; however, the issue of how temporary water retention might affect agricultural production has not received much analytical focus.

A study was conducted by Watts and Associates, commissioned by the FM Diversion Authority, to weigh in on several potential mitigation strategies and the potential viability of those strategies to address risk to producers that may experience flooding as a result of the Diversion. The paper largely outlined the existing strategies, including farm insurance, flowage easements, self-insuring, subsidized tile drainage, and land purchases. While each option has pros and cons, the paper concludes that "Development of the core elements for estimation of retention period length and financial impact are primary starting points."

This study represents the first attempt to address potential effects of temporary water storage on agricultural production resulting from the use of the FM Diversion. As a continuation of the FM Diversion Authority's evaluation of farm risk, this study aims to gain insights on flooding duration, variability of those effects based on land elevation and flood size, expected timeline for the effects of flooding to be gone, quantify the risk of delayed planting and its potential financial impact on producers.

Addressing those issues should be valuable in advancing the discussion of how agricultural production might be affected by temporary water storage. Despite this study's in-depth examination of the hydrology effects and potential planting delays, several important issues remain unquantified. While this project was not able to address all production-related issues, this study, along with its methodology, lays a strong foundation from which additional agricultural production questions can be addressed.

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Glossary of Terms

Affected Acreage	Total acreage of storage area that has some flooded acreage, even if the inundation does not cover the entire storage area. For example, if a storage area is 500 acres in size, but only 200 acres are submerged with flood water, the flooded acreage is 200 and the affected acreage is 500.
Days of Delay	The difference in total days between the Without and With Diversion conditions, and does not necessarily reflect the number of days a producer may be delayed. For example, a storage area has 20 total days (days to flood, days of inundation, and dry-down) for Without Diversion conditions and 25 totals days With Diverison. The days of delay due to the Diversion is 5 days; however, the number of days of planting delay may be more, the same, or less than the 5 days of difference between conditions—it just depends upon when regional planting begins.
Distribution	The range of a known value given the statistical characteristics of the underlying information or data. It represents the relative number of times each possible outcome will occur in a number of trials or replications. Values in a distribution often are combined with the probability of that value occurring over a specified period or under a specific set of conditions.
Dry-down	A period for the land to dry out to the extent that normal field operations may occur. The dry-down period was assumed to include time for removal of flood residue.
Effects of Flooding are gone	In this study, 'effects of flooding are gone' refers to when a storage area has gone through the required dry-down period. At that point, the land may be planted (if regional planting has started) or in the situations where regional planting has not begun, those lands will have to wait for general conditions to improve before planting.
Existing Conditions/ Without Diversion	Refers to the hydrology-related conditions currently present within the staging area and within each individual storage area. "Existing conditions" is synonymous with the terms "Without Diversion."
Flood Event	Spring flood event resulting primarily from snow melt that are sufficiently large to require use of the staging area as part of the FM Diversion.
Flooded Acreage	Only the actual acreage of lands within storage areas that are inundated (submerged) with flood water. These acreages can be equal to the total size of the storage area if the entire storage area is submerged or can represent a portion of acreage within a storage area.
Flood Start	The calendar date when the Red River reaches 17,000 cfs in Fargo. Snow melt and runoff would already be occurring prior to this date so the definition does not necessarily define when a spring flood event actually begins.

Flood Size/Frequency	Flood size or frequency is usually defined by the annual likelihood that the event would occur in any given year. The annual probability of a flood event occurring is inversely related to the size of the flood event; a 25-year flood event is smaller than a 50-year flood event. The annual chance of 25-year flood event is 4 percent whereas the annual chance of a 50-year flood event is 2 percent.
Gross Revenue	Defined as crop yield times crop price. Insurance indemnities and federal farm program payments are excluded.
Hydrology	In this study, hydrology is used as a general reference to the flooding or lack of flooding currently being modeled for storage areas within the staging area. The hydrology information used in this study is the result of modeling the distribution, movement, and volume of flood waters in the southern Red River Basin.
Monte Carlo	A Monte Carlo simulation is an analysis technique that allows for a range of outcomes to be evaluated based on the statistical distribution(s) of the values. The technique uses a random selection of possible model inputs by 'pulling' a value from a statistical distribution. The technique is helpful in defining the frequency, probability, and risk associated with a large number of potential outcomes.
Period of Record	The range of years of basin hydrology that was used by the U.S. Army Corps of Engineers for FM Diversion project design and evaluation. The period of record is 1942 through 2009.
Replication	Defined in this study to represent one combination of the factors generated in the Monte Carlo simulation. A replication would be analogous to the combinations present in one particular year.
Risk	Risk is a term often used to describe financial situations where the outcome of a particular set of conditions may not be known but the odds of occurring can be reasonably measured.
Staging Area	'Staging Area' refers to the area of the FM Diversion project where water will be temporary during spring flood events. Retention of water will be created through man-made levies and natural topography. Water collected in the staging area will subsequently be drained away through the Red and Wild Rice rivers and the Diversion channel.
Staging Activation	The calendar date during a spring flood event when the staging area would begin storing water. Staging activation date, in this study, is when the Red River reaches 17,000 cfs in Fargo, even though the Diversion will likely be activated prior to the Red River reaching 17,000 cfs in Fargo using gauges and flow monitoring upstream of Fargo.
Standard Deviation	A measure of how widely values deviate or differ from the average. Standard deviation is a common measure of variability.

Storage Area	Geographic units within the staging area that are delineated by man-made (e.g., roads) and natural features. The effects of temporary water storage were treated equally for all acres within an individual storage area. These areas are identified by range, township, county, acreage, and elevation (msl). For hydrology purposes, the storage areas are treated as one homogenous tract.
Target Yield	Yield that agricultural producers strive to obtain and adjust the level of inputs and farm practices to achieve.
Total days	The number of days between when the staging area is activated and the end of the dry-down period. That period may or may not differ between existing conditions and conditions expected with use of the Diversion.
Uncertainty	Uncertainty is a term used applies to situations where it may be impossible to reasonably measure the odds of something occurring.
With Diversion	Refers to the hydrology conditions that are expected to prevail during large spring flood events when the FM Diversion project is operational.

Initial Assessment of the Agricultural Risk of Temporary Water Storage for FM Diversion

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Executive Summary

The proposed Fargo/Moorhead Area Diversion (FM Diversion) is intended to reduce the flood risk for Fargo, Moorhead, and other communities in Cass County, North Dakota and Clay County, Minnesota. The FM Diversion is comprised of a water storage embankment and tie-back levies upstream of Fargo, flood protection dikes in the Fargo/Moorhead communities, and a Diversion channel to route water around the Fargo/Moorhead/West Fargo metro area. The embankment, tie back levies, and natural rise in the Red River basin will create a staging area in which water will be temporarily collected during times of high flow during spring flood events.

The implications of temporary water storage raise a number of questions, such as the effects of inundation on public infrastructure (e.g., roads, bridges), cultural landmarks (e.g., cemeteries), residential and commercial structures, delivery of public services (e.g., fire and rescue), and agricultural lands. This study is a preliminary evaluation of how temporary water storage during spring flood events may influence agricultural production within the staging area.

Current design of the FM Diversion is that temporary water storage will occur during spring flood events when the predicted flow of the Red and Wild Rice Rivers is expected to exceed 17,000 cfs in Fargo. Ten flood events since 1969, all occurring in the spring, would have triggered use of the FM Diversion using that criterion. The flow of the Red River at Fargo has not exceeded 17,000 cfs more than once within a year's time.

Study Approach

In an attempt to provide a broad assessment of the potential agricultural effects, **the study included the following factors:**

- **Gross revenues:** Revenues from crop production in the staging area during flood years Without the Diversion and With the Diversion.
- **Flood event start dates:** Range of likely dates when the staging area would be activated based on historical observations of when the Red River has reached 17,000 cfs in Fargo.
- **Regional planting start dates:** Dates when spring planting begins.
- **Planting rates**: Time required to plant crops based on overall spring planting conditions.
- **Agronomic considerations:** Crop rotations, periods when planting delays result in yield losses, dates when crops may be switched, and dates when crops would qualify for prevented planting.
- **Crop yields:** The anticipated yields that agricultural producers strive to obtain and adjust the level of inputs and farm practices to achieve. Crops modeled were wheat, corn, sugarbeets, and soybeans. The percentage of each crop was based on county-level planting data.
- **Yield reduction functions:** Amount of target yield lost due to delays in planting.

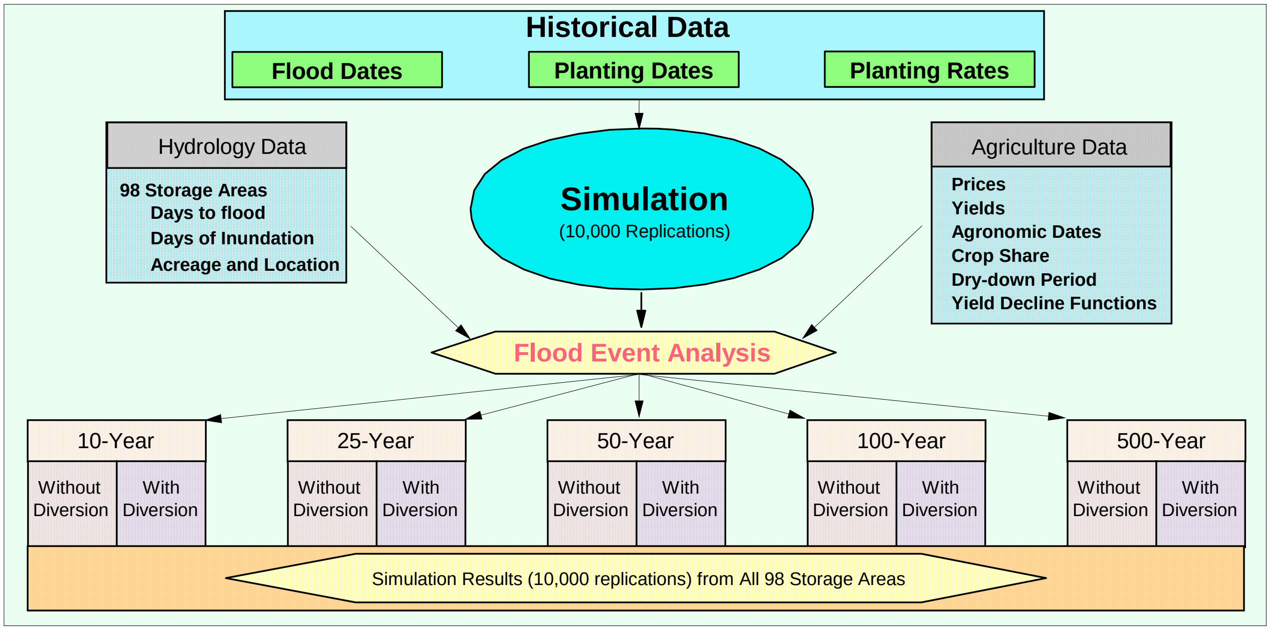
- **Crop prices**: A 7-year Olympic average of marketing year prices.
- **Dry-down period**: A 10-day period was used to represent the time necessary for the land to dry-down and complete any required clean up after being inundated, With or Without the Diversion.
- **Hydrology Data:** FM Diversion Authority provided detailed hydrology data for 98 storage areas comprising 44,285 acres.
    - **Flood Size** – 10-year, 25-year, 50-year, 100-year, 500-year, and 1997-like flood events
    - **Acreage Flooded**—acreage of land inundated based on general field elevation and size of flood event.
    - **Duration of Flooding**— days storage areas were flooded and when flood waters leave the storage areas.
    - **Without Diversion and With Diversion**—both hydrology conditions were modeled.
    - **Flood Effects vary by Storage Area and Flood Size**

      Hydrology Group 1 - Areas that do not flood With or Without the Diversion
      Hydrology Group 2 - Areas that already flood but flood duration is unchanged With Diversion
      Hydrology Group 3 - Areas that already flood but flood duration is longer With the Diversion
      Hydrology Group 4 - Areas that already flood but flood duration is shorter With the Diversion
      Hydrology Group 5 - Would not normally flood but will now flood With Diversion

      Excluding the 10-year flood event, the majority of acreage evaluated in this study will either flood longer (Group 3) With the Diversion or will now flood (Group 5) With the Diversion.

- **Key Assumptions and Omissions**:
    - **Crop Insurance** – the implications of Federal crop insurance coverage for lands affected by operation of the Diversion staging area were not addressed. Loss of Federal crop insurance mitigation of spring flooding would increase the per-acre losses on some lands and increase overall losses in the staging area during a flood event.
    - **Affected Acreage** – if any portion of a storage area was inundated all acreage of the storage area was assumed to be affected. This assumption could increase the overall acreage affected by spring flooding but would not affect the per-acre losses.

A Monte Carlo simulation, using historical data, was used to generate 10,000 most-likely combinations of flood starts, planting rates, and planting start dates. Hydrology data, combined with a dry-down period, were used with the Monte Carlo simulation to estimate the conditions, frequency, and magnitude of planting delays.



Historical Data
Flood Dates
Planting Dates
Planting Rates
Hydrology Data
98 Storage Areas
Days to flood
Days of Inundation
Acreage and Location
Simulation
(10,000 Replications)
Agriculture Data
Prices
Yields
Agronomic Dates
Crop Share
Dry-down Period
Yield Decline Functions
Flood Event Analysis
10-Year
25-Year
50-Year
100-Year
500-Year
Without Diversion
With Diversion
Simulation Results (10,000 replications) from All 98 Storage Areas

Results

The study focused on **1)** the additional time the Diversion adds to the number of days for the effects of flooding to be gone, and **2)** how often those additional days are likely to result in planting delays. A storage area would have delayed planting if the combination of inundation and dry-down periods extended past the date when regional planting starts. Conversely, if the combined time of inundation and dry-down occurred prior to when regional planting started, there would be no planting delays and the storage area would be planted at the same time as other land in the region. These criteria were applied to both existing conditions (Without Diversion) and With Diversion.

- Combining a **dry-down period** with the **hydrology data** revealed:
  - A majority of acres will require a total of 16 to 25 days for effects of flooding to be gone after activation of the staging area.
  - A majority of acres in the study area will flood Without the Diversion for most large flood events, and the Diversion will add 1 to 7 days of additional time for the effects of flooding to be gone.
  - Between 10,000 to 13,000 acres (depending upon flood event size) will flood due to the diversion that would not otherwise flood, and the time for the effects of flooding to be gone on those lands varies from 16 to 25 days after activation of the staging area.

- Examining **regional planting start dates** and likely **flood event start dates** revealed:
  - Annual probability ranges from 40 to 60 percent that the majority of acreage in the staging area, either with existing conditions or With the Diversion, would experience some planting delay for corn, sugarbeets, and wheat in a flood year (i.e., flood year of sufficient size to activate the staging area).
  - Annual probability is less than 15 percent that the majority of acreage in the staging area would experience some planting delays for soybeans in a flood year.

The study focused on those storage areas that flood longer (Group 3) and those storage areas that floods with use of the Diversion but would not otherwise experience spring flooding (Group 5).

Annual Chance of Revenue Loss due to Delayed Planting from Operation of the Diversion						
	Size of Flood Event					
	10-Year	25-Year	50-Year	100-Year	500-Year	1997-like
Storage Areas that Flood Longer With the Diversion (Group 3)						
Any Revenue Loss	33%	64%	67%	75%	75%	91%
$1 to $25 per acre	33%	64%	67%	75%	75%	91%
More than $25 per acre	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Storage Areas that Floods With the Diversion but would not Flood under Existing Conditions (Group 5)						
Any Revenue Loss	29%	50%	56%	60%	60%	78%
$1 to $25 per acre	28.5%	45%	48%	48%	46%	52%
More than $25 per acre	0.5%	5%	8%	12%	14%	26%

Note: *Per-acre revenue losses represent a composite of corn, wheat, soybeans and sugarbeets, based on their respective share of county crop acreage. Therefore, losses per acre for any hydrology group represent an average of the storage areas within that group and an average of revenues from all crops, even if some crops did not experience a planting delay or revenue loss.*

Despite the high probability of a planting delay during a 25-year or larger flood, the overall average per-acre losses within the storage areas was relatively small. Average losses were modest as a result of averaging all replications (years) with no losses (e.g., early flood with late regional planting start) and averaging all revenues from soybeans, which have little revenue loss and represent the largest share of acreage among the four crops (e.g., over 50 percent in Cass County).

Estimated revenue losses, averaged for all acres within the hydrology groups, are unlikely to equal event-level revenue losses for individual producers. For example, for those producers planning on raising soybeans, the probability and magnitude of revenue losses are quite low. However, for a producer raising corn in the same storage area, the planting delays due to the Diversion may result in revenue losses substantially larger than the average reported for the overall storage area or hydrology group.

Range of Per-Acre Crop Losses Observed in the Study, Storage Areas the Flood Longer

	10-Year	25-Year	50-Year	100-Year	500-Year	1997-Like
			-------------------------------- Corn --------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$0.75	-$5.46	-$6.16	-$9.16	-$5.54	-$12.61
Max (5%)	-$5.08	-$21.65	-$22.66	-$28.68	-$18.23	-$29.64
			--------------------------------- Wheat ---------------------------------			
Least (5%)	$0	$0	$0	$0	$0	-$0.01
Average	-$1.35	-$8.72	-$9.63	-$13.21	-$8.60	-$16.63
Max (5%)	-$6.66	-$23.47	-$24.13	-$30.06	-$20.06	-$29.34
			----------------------------- Sugarbeets -----------------------------			
Least (5%)	$0	$0	$0	$0	$0	-$0.02
Average	-$0.44	-$18.25	-$20.61	-$28.65	-$18.95	-$36.68
Max (5%)	-$2.61	-$51.81	-$53.84	-$68.22	-$44.73	-$64.73
			------------------------------- Soybeans ------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	$0	-$0.01	-$0.02	-$0.07	-$0.03	$0.56
Max (5%)	$0	-$0.30	-$0.45	-$1.33	-$0.63	-$7.04

Note: Five percent average of minimum and maximum observations controls for low probability events. Average values were estimated from all 10,000 observations in the analysis.

Range of Per-Acre Crop Losses Observed in the Study, Storage Areas that Now Flood (new flooding)						
	10-year	25-year	50-year	100-year	500-year	1997-Like
			Corn			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$2.99	-$6.94	-$6.84	-$8.96	-$9.81	-$18.03
Max (5%)	-$29.98	-$49.60	-$48.73	-$57.66	-$61.10	-$79.77
			Wheat			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$5.89	-$12.76	-$12.06	-$15.76	-$17.22	-$27.63
Max (5%)	-$51.07	-$76.23	-$73.12	-$84.10	-$88.28	-$102.45
			Sugarbeets			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$1.81	-$27.25	-$25.60	-$33.67	-$36.75	-$58.81
Max (5%)	-$16.77	-$163.08	-$156.50	-$179.97	-$188.08	-$219.31
			Soybeans			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	$0	$0	$0	-$0.01	-$0.01	$0.09
Max (5%)	$0	-$0.05	-$0.07	-$0.14	-$0.16	-$1.73

Only losses due to the operation of the Diversion were estimated. Excluding the 10-year flood event, average losses per acre for corn ranged from $7.50/acre in the 25-year event to $10.25 per acre in the 500-year event. Per-acre losses for soybeans averaged less than $0.10 for all flood event sizes. Excluding the 10-year flood event, average losses per acre for wheat ranged from $12.50/acre in the 25-year event to $16.25 per acre in the 500-year event. Sugarbeets had the largest per acre losses, ranging from $26 per acre in the 25-year even to over $34 per acre in the 500-year event. The per-acre losses reflect averaging of all storage areas in Groups 3 and 5, and included years when the operation of the Diversion did not result in revenue losses.

The collective revenue losses, for any single flood-event size examined in this study, when examined over all 10,000 replications for all 98 storage areas, ranged from $0 in the best-case situations to near $2 million in the worst-case situations. Those estimates did not include any Federal crop insurance indemnities associated with delayed planting.

Conclusions

Overall, the economic impact of Diversion Operations on crop production in the 98 storage areas was modest. In evaluating the historical data and expected differences in flooding created by the Diversion, several reasons underpin this conclusion.

There are no recorded flows on the Red River due to rain that would trigger the use of the Diversion; the Diversion would only be used to protect against springtime rain and snow melt. The Diversion is not expected to create losses after spring planting season.

Spring snow melt and runoff, in most cases, occur early relative to the regional planting season. During much of the flood-event, no planting occurs due to snow melt and overall wet conditions. The historical data suggest there was limited overlap between the spring runoff and planting.

The engineering data indicate that the combined capacity of the Red River and the Diversion channel, once the community is protected with dikes, will move extensive amounts of water around the community. The exact amount and timing will not be known until the Diversion Operating Manual is finalized by the Corps, but the preliminary indications are that the Red River will handle 17,000 cfs through the community and the Diversion channel will handle an additional 22,000 cfs around the community. However, despite the stated capacities, the timing and flow of flood waters also will be based on the characteristics of the flood-event, and all floods are unique (e.g., compare the 1997 flood event to the 2009 flood event). The combined flow capacity of 39,000 cfs clearly exceeds the largest observed flow in Fargo of 29,800 cfs observed in 2009. Both the stated design capacity of the Diversion and the current hydrology data suggest that water will not be retained in the staging area for extensive periods, and it is highly likely that those lands will be planted in a flood year.

In the more modest flood events (e.g., 25-year and 50-year events), many storage areas are not adversely affected by the Diversion. A substantial portion of the 98 storage areas, most lying in relatively low elevations, would experience flooding Without the Diversion. Current hydrology modeling suggests that the majority of lands that would flood Without the Diversion will experience 1 to 7 days of additional time for the effects of flooding to be gone (Group 3). For those lands, the Diversion may contribute to a delayed planting but is not responsible for all of the delayed planting. Most lands that will experience new flooding With the Diversion (Group 5) would require up to 25 days from the date when the staging area is activated until the effects of flooding are gone. However, not all of those days translate directly into planting delays. For much of that period, general weather conditions, such as temperature and normal dry-down from snow melt, prevent spring planting.

The impacts of planting delays from Diversion operations on corn, wheat, and sugarbeets are likely to be substantially different than soybeans. Soybeans had the lowest frequency and magnitude of revenue loss of the four crops. Soybeans also have the lowest relative yield decline of the four crops when planted beyond the optimal period. Over the planting periods evaluated in this study, planting delays have less relative impact on soybeans than corn, wheat, or sugarbeets. Soybeans also are planted later in the spring, reducing the likelihood of planting delays due to the use of the staging area. This combination of factors is why soybeans have the lowest per-acre revenue losses. Soybeans also comprise the largest share of crops grown in the staging area, which further reduces the average revenue losses when all crop losses are combined within an entire storage area.

Operation of the Diversion creates a high likelihood of modest planting delays and subsequent revenue loss. About 30,000 to 38,000 acres (depending upon flood size) have a 50 percent to 65 percent chance of a revenue loss in a flood year (excluding 10-year events or smaller).

While the probability of a revenue loss is high, the magnitude of losses is generally modest (less $25/acre average for a storage area). The probability of revenue loss of $25 to $75/acre average within a storage area is about 10 percent for flood events larger than a 10-year event.

Due to the complexity of the hydrology, which varies by storage area for the flood events evaluated, generalized statements about how producers will be individually affected are difficult. Revenue losses across all acres and crops within a storage area and by hydrology group measures the potential cumulative losses in the staging area and identifies general risk. However, care should be exercised that generalities and averages mask substantial differences for individual crops and storage areas. The economic impacts on some agricultural producers are likely to be considerably different from the average values within the hydrology groups.

Per-acre losses and cumulative losses would be larger if Federal crop insurance indemnities were included. Several uncertainties exist with how Federal crop insurance would be administered in the cases where the Diversion adds to existing flooding but the land would have flooded in the absence of the Diversion. Also in cases where the Diversion is modeled to have no adverse effect, questions remain if the use of the Diversion affects the eligibility of Federal crop insurance to assist in mitigating planting delays on those lands. To what degree Federal crop insurance coverage will be impacted as a result of Diversion operations is unknown. This study only estimated the revenue losses associated with delayed planting that was due to operation of the Diversion. Including the potential value of lost insurance on all lands experiencing a planting delay (regardless if the planting delays was due to the Diversion) would increase the losses to producers and perhaps substantially increase losses Calculated in this study.

Total losses in this study were based on the assumption that if any portion of a storage area was inundated, all land within that storage area was equally affected. Given the lack of available data to refine that assumption, developing estimates using all acreage was the best approach. However, overall losses due to the use of the Diversion would be sensitive to that assumption. Also if the acreage modeled was expanded to include ‘cross-section’ areas excluded from this study or additional lands beyond the 98 storage areas, overall losses would likely increase. Finally, including the value of lost insurance indemnities would increase total losses.

This study represents the first attempt to address potential effects of temporary water storage on agricultural production resulting from the use of the Diversion. As a result of this effort, insights were gained on how the flooding effects vary by location and elevation of land, and how the effects also are influenced by the size of flood event. Examining when the effects of flooding may be gone and when regional planting typically begins, suggests a high likelihood of relatively short planting delays. These conclusions are extremely helpful in advancing the discussion of how agricultural production might be affected, but a number of additional issues remain unquantified. While this project was not able to address all production-related issues, this study, along with its methodology, lays a strong foundation from which additional production questions can be addressed.

Recommendations

-) **All lands affected by temporary water storage due to the operations of the Diversion need to be assessed**.

The 98 storage areas evaluated in this study exceedes the general scope of the staging area as previously defined by the U.S. Army Corps of Engineers. Despite the expanded geography of lands that may be potentially impacted, potential effects for substantial acreage within the study region were not included in this study. All lands impacted by temporary water storage associated With the Diversion should be assessed. Those areas may include lands with hydrology impacts less than the Federal threshold for mitigation. Some of those lands are currently classified as 'cross-section' areas in the hydrology modeling. Producers operating in those areas will have no less desire to understand the hydrology effects and potential economic risk than producers operating in the storage areas identified in this study.

-) **Insurance Implications**

Evaluate the potential loss of insurance indemnities during flood years and potential effects of reduced yields in flood years on adjustments to a producer's annual production history. Implications associated with effects on federal crop insurance could be substantial.

-) **Improve upon Key Assumptions**

Study results are sensitive to dry-down assumptions. The days required for dry-down and clean-up was a static assumption, but should be re-examined to evaluate if dry-down periods can be statistically linked to planting rates or related to weather differences generally observed between the months of April and May.

Refinement in general data may require cooperation from producers operating within the staging area or cooperation from government agencies (e.g., Risk Management Service). County- or state-level information for crop yields, planting periods, planting rates and other agricultural factors were used in this assessment. More refined data, specific to the general staging area, would provide more precise estimates of the economic effects.

-) **Variability of Effects at Producer Level Highlight Need for a Fair, Flexible, and Comprehensive Compensation Policy**

This study demonstrates the complexity of framing and measuring the impacts of temporary water storage on agricultural producers. The FM Diversion Authority should continue to evaluate alternative compensation adjustments and mitigation strategies. Potential elements could include relieving risk to tenant producers, not just landowners. A compensation plan addressing full damages and including all affected parties would help alleviate the risk and financial concerns associated with temporary water storage.

Initial Assessment of the Agricultural Risk of Temporary Water Storage for FM Diversion

The proposed Fargo/Moorhead Area Diversion (FM Diversion) is intended to reduce the flood risk for Fargo, North Dakota, Moorhead, Minnesota and other communities in Cass County, North Dakota and Clay County, Minnesota. The project is being pursued by the Flood Diversion Board of Authority (Diversion Authority) in collaboration with the U.S. Army Corps of Engineers (Corps).[1] Major components of the project are:

- A "Southern/Tieback Embankment" extending "west to east" from Cass County Road 17 (south of Horace, North Dakota), crossing the Red River of the North (the North Dakota/Minnesota boundary), and continuing to Minnesota Highway 11 in Clay County. The total length of the Southern/Tieback Embankment would be approximately 12 miles. The Southern/Tieback Embankment would be constructed along 124th Avenue South in North Dakota, and located between 120th Avenue and 130th Avenue South in Minnesota.

- A second feature is an "Overflow Embankment" in North Dakota that extends south from the west end of the Southern/Tieback Embankment for a distance of approximately 4 miles along County Road 17 in Cass County, North Dakota.

- A third feature of the project are flood protection dikes in the Fargo/Moorhead communities (north of the Southern/Tieback Embankment) along the Wild Rice and Red rivers to protect the communities and increase the capacity of the two rivers as they flow through the communities. The combined 1-percent event flow through the Red River and Wild Rice River control structures, once the protection is in place, will be 17,000 cubic feet per second (cfs). The Wild Rice River flows into the Red River about three miles north of the proposed Southern/Tieback Embankment. The Red River continues to flow north from that point.

- A fourth feature of the project is a Diversion channel to flow flood water around the Fargo/Moorhead/West Fargo communities. This channel will begin at the northwest corner of the embankment (where the Southern/Tieback Embankment connects to the Overflow Embankment) and extends around the west side of the communities for a distance of approximately 30 miles before draining into the Red River at a point north of the City of Harwood, North Dakota which is located several miles north of Fargo/West Fargo. The Diversion channel will flow into the Red River about 25 miles north (downstream) from the Southern/Tieback Embankment.[2]

The Southern/Tieback Embankment on the north, the Overflow Embankment on the west, and the natural rise in the land in Minnesota on the east form a basin or "staging area" in which water will be temporarily collected during times of high flow during spring flood events (Figure 1). Water collected in the staging area will subsequently be drained away through the Red and Wild Rice rivers and the Diversion channel according to an Operating Manual being prepared by the Corps. .

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[1] Additional information is available on the FM Diversion web site http://www.fmDiversion.com/authority.php

[2] Additional materials and information on the physical dimensions and placement of key elements of the FM Diversion can be found on the FM Diversion web site http://www.fmDiversion.com/pdf/StructureFeatures20140401_1117.pdf

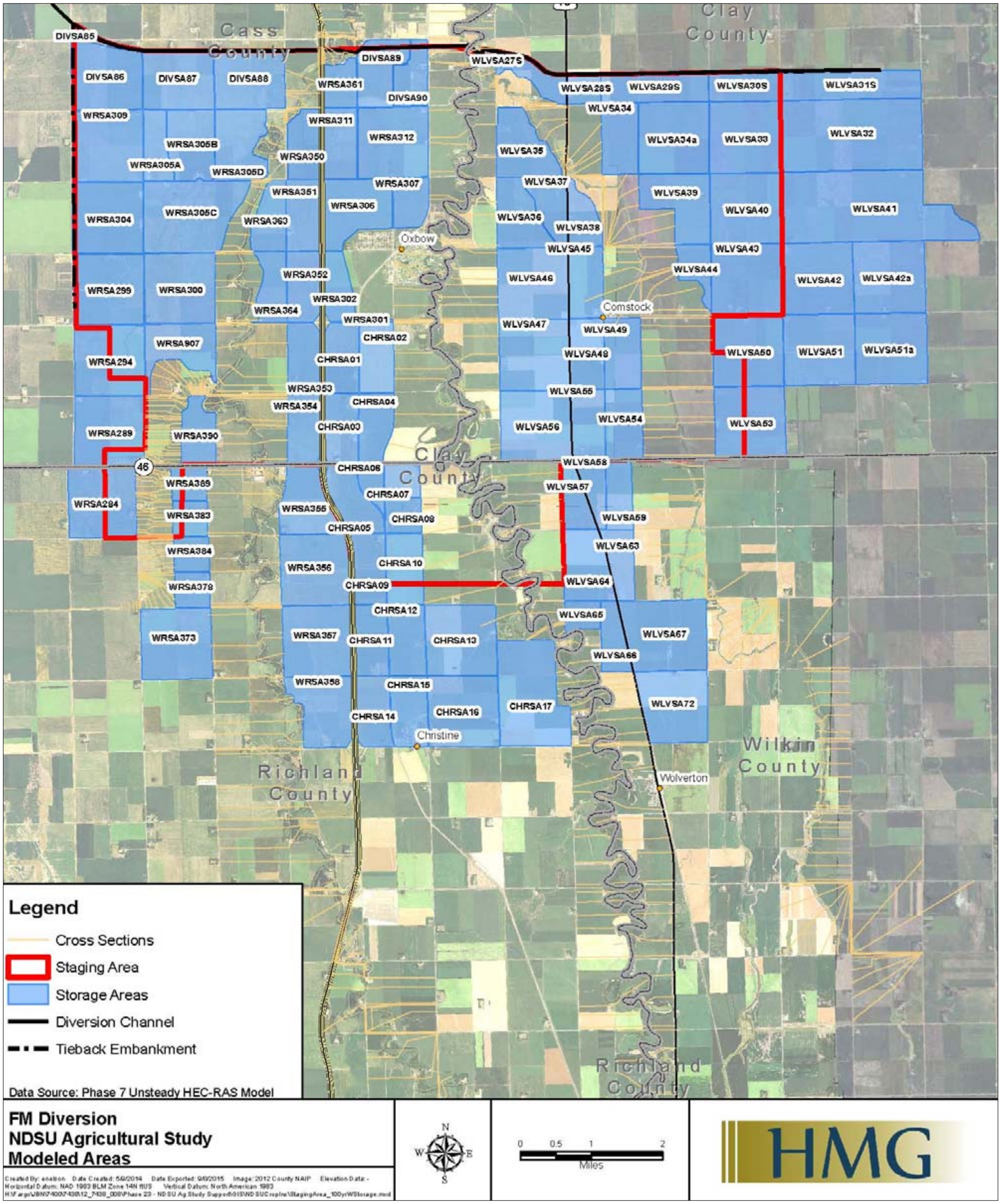

Figure 1. Storage Areas Associated With FM Diversion Staging Area, 2015
Source: FM Diversion Authority (2015).

The Red River and the Wild Rice River are the primary sources of water flowing into the staging area. Other nearby rivers, such as the Sheyenne River in North Dakota and the Buffalo River in Minnesota will not likely contribute water to the staging area. Large flood events on the Sheyenne River can result in breakout flow that would make it into Richland County Drain 37 and then into the staging area. Water will not be collected in the staging area unless the combined flow of the Red and Wild Rice Rivers exceeds 17,000 cfs in Fargo. The Corps indicates it will monitor the flow of the two rivers upstream of Fargo to determine when to begin staging water (i.e., activate the Diversion).

An indicator of the combined flow of these two rivers is the historic flow of the Red River at Fargo, which is downstream from the confluence of the Wild Rice and Red rivers. United States Geological Survey (USGS) data indicate that the flow of the Red River in Fargo has reached or exceeded 17,000 cfs 10 times since 1943 (Table 1).[3]

All ten of the high flow events have occurred since 1969; three of which occurred consecutively from 2009 through 2011. The most extensive flood events occurred in 1997 and 2009. These recent occurrences raise concern that larger flood events may be more frequent (10 times in 46 years) than suggested by long-term historical data (10 times in 73 years). The flow of the Red River at Fargo has not exceeded 17,000 cfs more than once within a year's time.

Table 1. Dates When Red River Exceeded 17,000 Cubic Feet per Second at Fargo, North Dakota

Years	Dates	Maximum CFS
1969	April 13 to April 18	24,800
1978	April 3	17,000
1979	April 19	17,200
1989	April 8 to April 10	18,600
1997	April 9 to April 28	27,800
2001	April 12 to April 17	20,200
2006	April 3 to April 7	19,800
2009	March 25 to April 3	29,100
2010	March 19 to March 24	21,100
2011	April 7 to April 17	26,100
Red River did not reach 17,000 CFS in 63 of 73 years from 1943 to 2015.		
Source: U.S. Geological Survey (2015).		

The Corps has defined various flood event sizes for the Red River at Fargo based on flow rates and probability of occurrence (Table 2). These definitions indicate the relationship between flow rates and flood events, for example, 17,000 cfs is a 10-year event meaning a flood event of that size has a 10 percent probability of occurring in any year. Federal Emergency Management Agency (FEMA) also uses flow rates and probability of occurrence to define flood events; however, FEMA's definitions of flood events based on probability of occurrence for Fargo have lower peak discharge rates than those used by the Corps (Table 2). The differences between FEMA and the Corps result from using different periods of record for flow data on the Red River

[3] Additional information on historical water flows can be obtained from the USGS web site http://waterdata.usgs.gov/nwis/dv?referred_module=sw&site_no=05054000.

Table 2. Historical Discharges, Red River in Fargo and Estimated Discharges and Probability of Occurrence			
Flood Event and Annual Probability of Occurrence	Peak Discharge (cfs) in Red River at Fargo		
		U.S. Army Corps of Engineers	
	FEMA	Expert Opinion[a]	Period of Record[a]
10-year 10%	10,300	17,300	13,865
50-year 2%	22,300	29,300	26,000
100-year 1%	29,300	34,700	33,000
500-year 0.2%	50,000	61,700	66,000
1997 Historical			28,000
2006 Historical			19,900
2009 Historical			29,500
2010 Historical			21,200
2011 Historical			27,200

[a] Expert Opinion was the conclusion drawn from a panel of experts engaged by the Corps to assess whether the whole period of record or a subset of the period of record should be used as part of the FM Diversion plan. The panel concluded that a subset of the period of record should be used.
Source*:* U.S. Army Corps of Engineers (2013).

The maximum or peak cfs for any event does not indicate the total volume of water during the event. The flood event of 1997, for example, contained more water than the 2009 flood event although the peak discharge rate for the 1997 flood event was lower than the discharge rate for 2009 flood event. The difference was that the 1997 flood event lasted for a longer time (20 days of flow in excess of 17,000 cfs compared to 10 days in 2009). When determining which land will flood, maximum flow is critical, but in this study where the analysis is focusing on land flooded due to stored water, total volume is the more critical consideration. Thus, the flow rate needs to be converted to a volume by incorporating a measure of duration of inundation.

The highest flow of the Red River in Fargo has been associated with spring flooding due to snow melt and rains during the snow melt period. The earliest that the flow exceeded 17,000 cfs was March 19 (2010) and the latest that the flow exceeded 17,000 cfs was April 28 (1997) (Table 3). The largest flow was in 2009 when the volume reached 29,100 cfs (based on USGS data). In two years (1978 and 1979), the flow reached 17,000 cfs for only one day. Occasional heavy summer rain has not increased the flow of the river above the critical volume of 17,000 cfs [for example, the flow of the Red River at Fargo reached 13,100 cfs in early July 1975 and early June 2007; there also was high water (about 10,000 to 11,000 cfs) in late June 2013 and June 2009]. Based on these data, it is assumed that a Diversion would have been operated ten times since 1943 (this count excludes 1978 because the flow peaked at 17,000 cfs).

As discussed in this report, the timing and duration of the flood event, relative to planting dates suggest the impact on agricultural production. Table 3 summarizes the time of spring melt and planting seasons for 200-2014 and 1997.

Table 3. Dates of Red River Spring Flows and Spring Planting Dates, 1997 through 2014								
Year	Flood Event Size	Date Fargo Flow Reached 17,000 cfs[a]	Maximum Fargo flow (cfs)	Date of Maximum Fargo Flow	Recorded Date Fargo Flow Declined to Less than 17,000 cfs[b]	Early Planting Start Date[c]	More General Planting Start Date[c]	Days available to Drain & Dry Land before Start of General Planting[d]
2000	No flood		3,060	Mar. 26		Apr. 16	Apr. 16	
2002	No flood		1,940	Apr. 1		Apr. 7	Apr. 27	
2003	No flood		1,780	Apr. 22		Apr. 13	Apr. 26	
2004	No flood		1,320	Mar. 28		Apr. 4	Apr. 18	
2005	No flood		3,990	Apr. 1		Apr. 10	Apr. 17	
2007	No flood		8,770	Apr. 6		Apr. 15	Apr. 21	
2008	No flood		2,220	Apr. 19		Apr. 13	Apr. 26	
2012	No flood		3,770	Mar. 19		Apr. 8	Apr. 15	
2013	No flood		15,900	Apr. 30		May 5	May 5	
2014	No flood		9,490	May 3		Apr. 20	May 10	
2006	25-year	Apr. 3	19,800	Apr. 5	Apr. 8	Apr. 16	Apr. 23	15
2001	25-year	Apr. 12	20,200	Apr. 14	Apr. 18	Apr. 22	May 6	18
2010	25-year	Mar. 19	21,100	Mar. 21	Mar. 25	Apr. 11	Apr. 18	24
2011	50-year	Apr. 7	26,100	Apr. 9	Apr. 18	Apr. 24	May 8	20
1997	50-year	Apr. 9	27,800	Apr. 17	Apr. 29	**na**	**na**	**na**
2009	50-year	Mar. 25	29,100	Mar. 28	Apr. 4	Apr. 19	May 3	29

[a] Perhaps a day or two after the Diversion would have been activated based on gauges south of Fargo

[b]Latest recorded date for peak acreage flooded due to the Diversion, assuming that out flow from staging area does not drop below 17,000 cfs while there is water in the staging area.

[c] Early planting date was defined as the first calendar date reported by National Agricultural Statistics Service for when spring planting begun. More General Planting date was defined to represent the date when about 20 percent of a crop has been planted. Both Early Planting and More General Planting dates are for wheat, corn, and sugarbeets.

[d] Time between date Fargo flow declines to less than 17,000 cfs and the general planting start date.

Implications for Agricultural Production

The implications of temporary water storage raise a number of questions, such as the effects of inundation on public infrastructure (e.g., roads, bridges), cultural landmarks (e.g., cemeteries), residential and commercial structures, delivery of public services (e.g., fire and rescue), and agricultural lands. This study focuses on evaluating how temporary water storage may influence agricultural production within the staging area.

The following points underpin the analysis:

- Net Impact - The impact of the proposed Diversion on production agriculture in the staging area is the difference between:
    - 1) the gross revenues from production agriculture in the staging area WITHOUT the Diversion
    - 2) the gross revenues from production agriculture in the staging area WITH the Diversion.

  Note: The measure of damage created by the FM Diversion should not to be confused with the difference between gross revenues in a flood year and gross revenues in a non-flood year[4].

  Note: Assume minimal impact on production cost except clean-up cost because…and when crop is switched.

- Flood Event Size - The staging area would be filled to capacity only in case of an extremely large (but also low probability) flood event (e.g., 100-year and 500-year events). Smaller flood events, even though their flow exceeds 17,000 cfs and would require water storage, are not likely to fill the staging area. Thus, the higher elevations in the staging area, such as 925 feet above mean sea level (msl), may rarely be impacted by the operation of the Diversion. The study needs to consider how acreage of land inundated will vary among flood event sizes based on general field elevation and volume of water associated with different flood events as opposed to peak or crest flow rate as opposed to peak or crest flow rates.

- Hydrology and Inundation - FM Diversion staging area primarily affects agricultural lands by either:
    - 1) Retaining water longer than would otherwise occur. In these circumstances, the lands would have flooded even Without the Diversion. Many of those areas are in lower relative elevations, and often experience spring flooding. The impact of the Diversion on these agricultural lands would result from the additional time the land remains inundated. The time required to clear debris and time necessary to dry out is NOT an impact of the Diversion because the land would have been inundated even Without the Diversion.
    - 2) Land that now floods that would not otherwise be inundated. These lands could potentially be impacted by the time that water is on the land and the time required for the lands to dry-down and to remove debris.

[4] This study only examines the effects of temporary water storage associated with spring flood events. Historical data suggests that the use of the staging area to retain flood water due to rain events during the summer is extremely unlikely. Therefore, the only perceived risk to agricultural producers would be associated with the use of the staging area during spring flooding.

- In both cases, the duration of inundation is a critical component of the analysis, and must be considered over a range of flood event sizes for land throughout the staging area.

- Flood Start Dates - Converting water storage duration and dry-down periods into planting delays must account for when a flood event occurs and how long the flood event lasts. Flood events do not occur on the same calendar date(s), nor do they always have the same duration. Therefore, the effects on agricultural producers can vary based on both the start date of the flood event and how long the flood event lasts.

- Spring Planting Dates - Spring planting does not start on the same date(s) every year. Planting conditions vary considerably; therefore, planting delays due to the Diversion cannot be estimated without also knowing when producers can typically begin planting.

- Planting Rates - Spring planting conditions are not always constant during a planting season, nor are they necessarily consistent among years. Therefore, conditions during the spring planting season also must be included in the analysis to account for how long it takes to plant a crop.

- Agronomic Factors - Agronomic considerations include crop rotations, yields, and time periods when planting delays result in yield losses.

- Crop Prices - Crop prices are an important part of farm revenue, yet prices vary almost annually and are unlikely to be the same for all flood years.

- Insurance Eligibility - There are repercussions of a man-made versus natural flood event for crop insurance eligibility. Producers stand to lose potential revenues from crop insurance during years when the staging area is used if similar insurance provisions or mechanisms are not available to them.

The economic impact of storing water in the staging area is the difference between the economic value of agricultural crop production in the staging area Without the Diversion and the economic value of agricultural crop production in the staging area when the Diversion is operated. A number of potential factors may affect a producer as a result of the Diversion, such as soil productivity changes resulting from erosion[5], additional costs to travel in and out of the region if farmsteads are moved/relocated outside the staging area, reduction in yield due to planting delays, reduction in revenues if crops cannot be planted, potential costs of post-flood cleanup, and potential effects on crop quality (e.g., sugar content in sugarbeets). Theoretically, the potential loss of value to agricultural land in the staging area arising from a restriction or abatement on future residential or commercial development should be mitigated through Federal easements. While a number of effects may warrant consideration from an agricultural producer's perspective, this study focuses only on the economic effects of planting delays on yields and producer revenues.

[5] Erosion has occurred in previous large flood events, such as the 1997 flood. Based on hydrographs showing the rate of water inundation and rate of water out flow between the Without Diversion conditions and With Diversion conditions, erosion may occur in the staging area on the in-fill or out-flow phases of operation. The issue of potential erosion of crop land has not been specifically addressed in the current hydrology modeling.

The following sections describe the data that were gathered to address the key study points and the analytical approaches, assumptions, and methods used to evaluate the key issues. Additional detail is contained in several appendices, and as well as throughout the report.

Data Sources

Information collected for the study includes historical information about when producers begin planting, rate of planting progress, crop yields, crop acreage, crop prices, frequency and severity of flood events, yield losses due to delayed planting, dry-down periods, and target yields for regional crops, in addition to hydrology modeling output for storage areas comprising a substantial portion of the FM Diversion staging area.

Planting Start Dates

The timing of crop planting in the Red River Basin is a function of weather, or more specifically, temperature and precipitation. In addition to when planting occurs, the time required to plant a crop also is affected by weather during the planting period. USDA National Agricultural Statistics Service (NASS) monitors spring planting progress for several crops in Minnesota and North Dakota. Planting progress data track when producers begin planting and the rate of acreage planted.

An important component in the analysis is to capture variability in spring planting conditions. NASS planting progress data identify the week when planting begins and then estimate cumulative percentage of acres planted in subsequent weeks. Often the first week of planting shows small percentages of acreage planted; small acreage also is planted in the final days of the planting season. The data imply that most of the acreage of key crops is planted over a short period, relative to the total planting time in any given year (Appendix A). Planting progress data for soybeans in North Dakota illustrates that the majority of acreage in most years is planted over a relatively short period, for example (Figure 2).

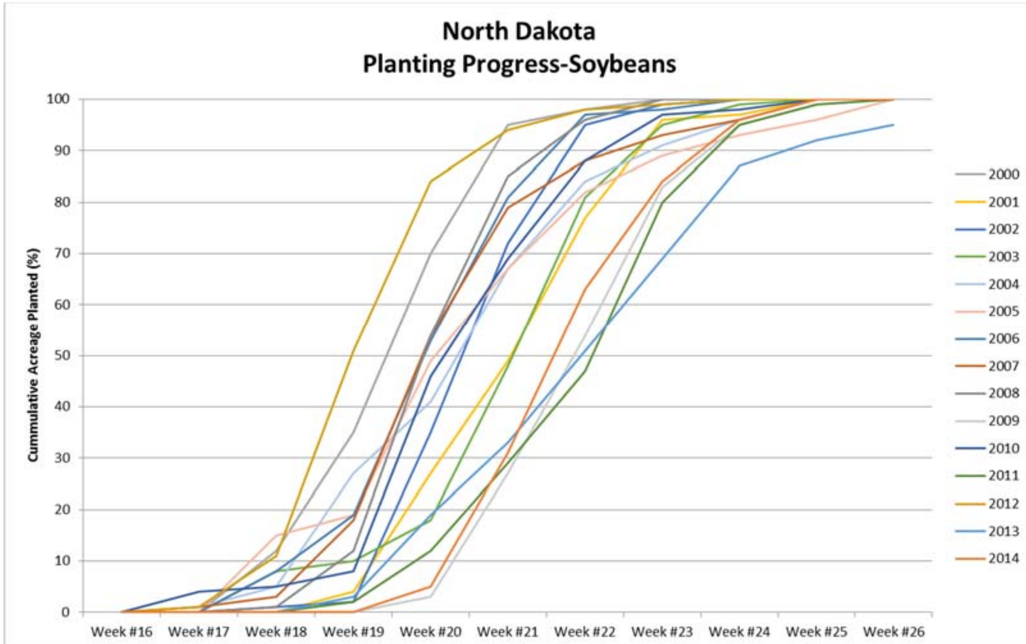

Figure 2. Statewide Planting Progress, Soybeans, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

The study region predominately grows corn, soybeans, sugarbeets, and wheat. A problem with statewide planting progress data is that spring planting conditions can vary considerably in different regions of the state. For example, planting progress for wheat is likely to be influenced by conditions in the western growing regions of North Dakota since the majority of wheat in the state is produced outside of the Red River Valley. Those effects also are a concern for progress data for corn and soybeans in Minnesota and North Dakota. Much of the soybeans and corn in Minnesota are raised south and east of the Red River Valley, and may not mirror planting conditions in the Red River Valley. Corn and soybeans have greatly expanded acreage to the west and north in the state. Therefore, statewide planting progress data for corn and wheat were not considered representative of historical conditions within the southern Red River Valley.

Planting progress data for sugarbeets in North Dakota predominately reflect conditions present in the Red River Valley. While a small percentage of acres are grown near the Montana border in western North Dakota, the vast majority of sugarbeets raised in North Dakota are in the Red River Valley. Planting start times for wheat and corn are similar to sugarbeets. Because statewide planting progress reports are influenced by conditions elsewhere in the state, NASS data on sugarbeet planting were used as a proxy for planting start dates for wheat and corn in the study region. Since soybean data specific to the Red River Valley were not available, the study used North Dakota statewide planting progress data for soybeans.

Planting Rates

A planting progress rate was based on the length of time for planting progress to move from 20 percent completion to 80 percent completion (Figure 3). Examining only the period from 20 to 80 percent planted eliminates the unique circumstances associated with early planting and late planting. The very earliest planting typically does not represent actions by the majority of producers, and can represent attempts to plant a crop that are not reflective of general planting conditions. Similarly after about 80 percent or more of the crop acreage is planted, the additional time to plant the remaining crop acreage is not representative of general planting conditions or the planting activities of most agricultural producers.

Planting progress data were used to estimate the annual variability in the seasonal planting conditions. Examining the percentage of acreage planted between 20 percent and 80 percent completion thresholds revealed considerable variation in planting conditions over the past 15 years (Figure 4). Those variations are reflective of the temperature and moisture conditions present during planting operations, and can vary depending upon crop and year (Appendix B).

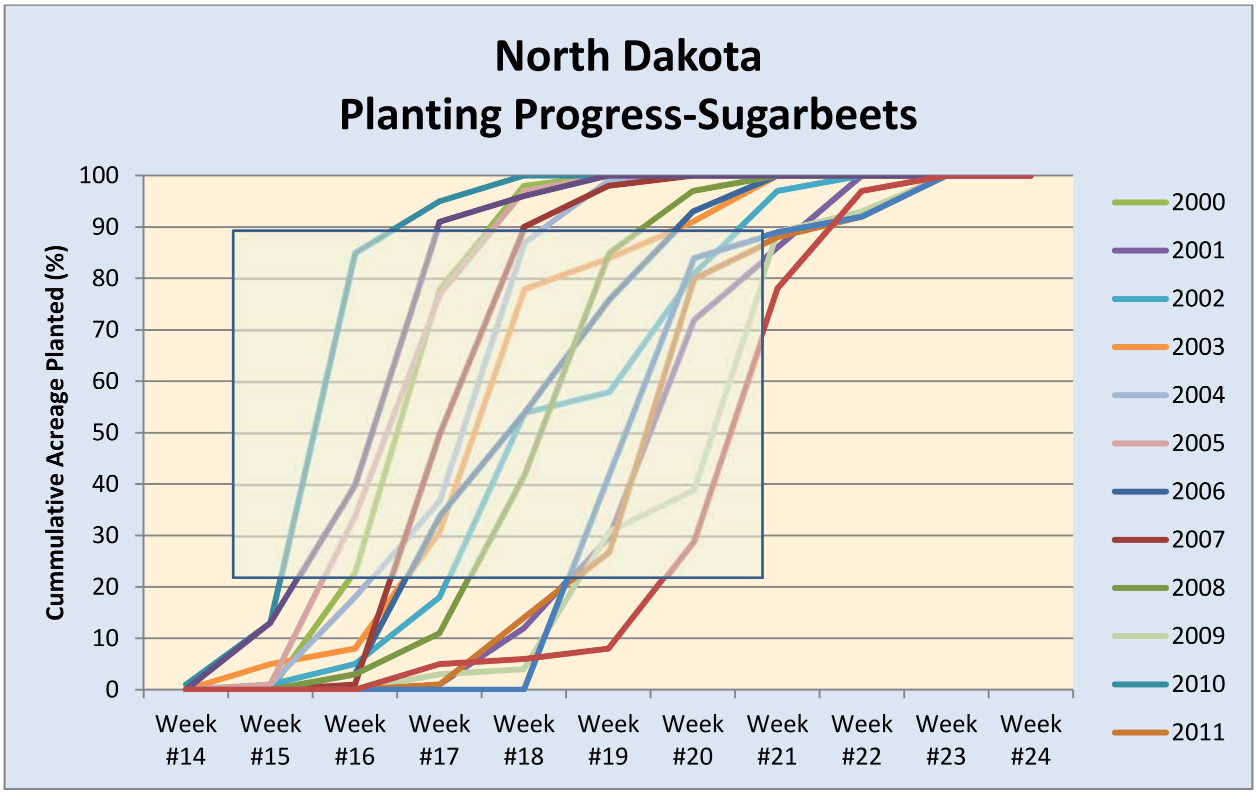

Figure 3. Example of Using of Statewide Planting Progress Data to Estimate Planting Rates between 20 Percent and 80 Percent of Planting Completion, Sugarbeets, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

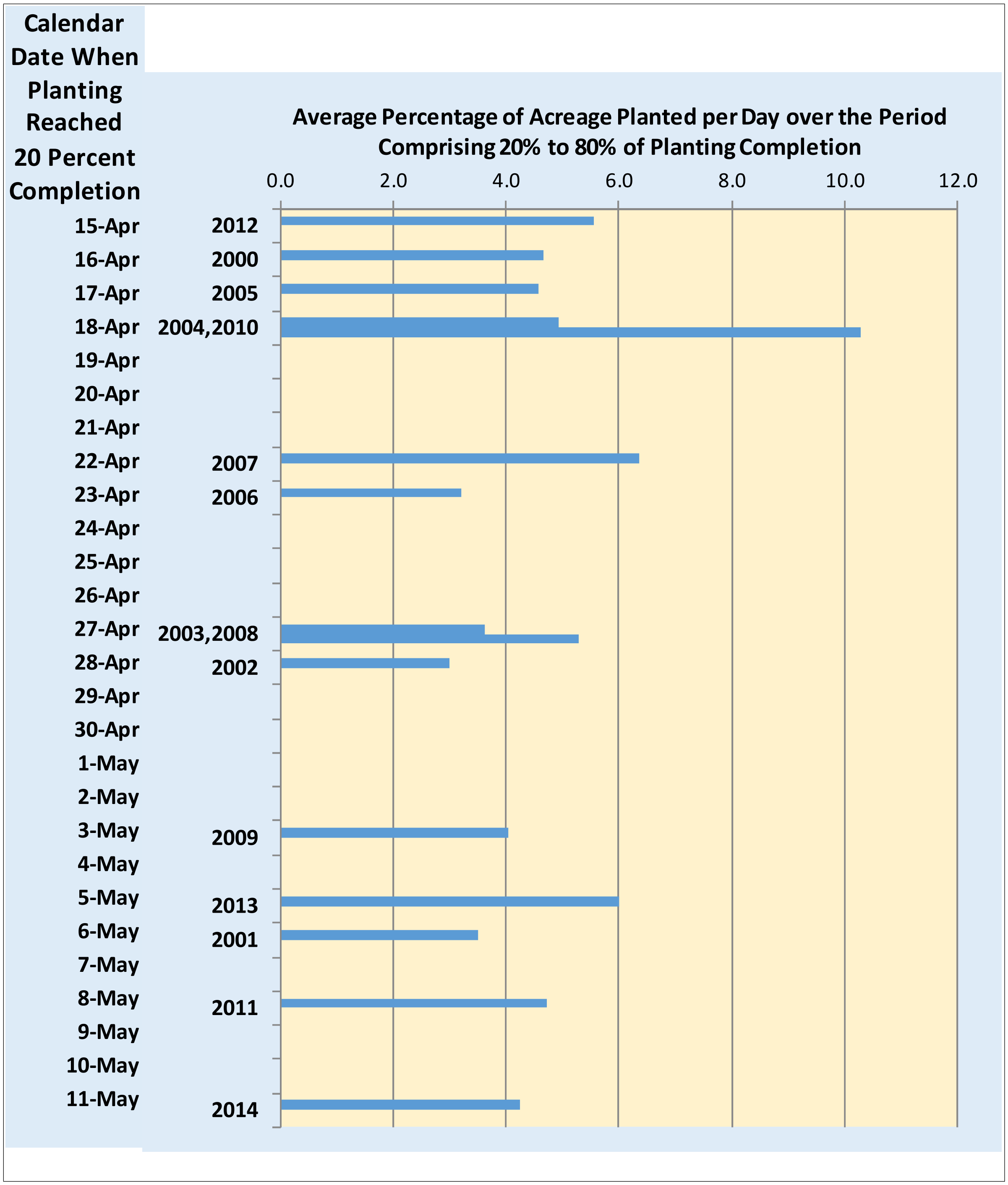

Figure 4. Average Daily Planting Rates for 20 Percent to 80 Percent of Planting Progress, and Calendar Dates when Planting Reaches 20 Percent Completion, Sugarbeets, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

Crop Share

Information on acreage of crops raised in the four-county study area was obtained from NASS (2014). Predominant crops in the study region since 2000 have been corn, soybeans, sugarbeets, and wheat. Other crops are raised in the study region, but data for Cass and Richland Counties indicate that those crops comprised a small portion (7 percent) of all planted acreage in 2014 (USDA Farm Service Agency 2014). Acreage planted to soybeans has remained relatively stable while corn acreage has increased and wheat acreage has decreased from 2000 through 2014 (Figures 5 and 6). A three-year average from 2011 through 2013, by county, was used to estimate the crop share percentage in the staging area (Table 4). Those percentages remained constant across all of the flood event sizes.

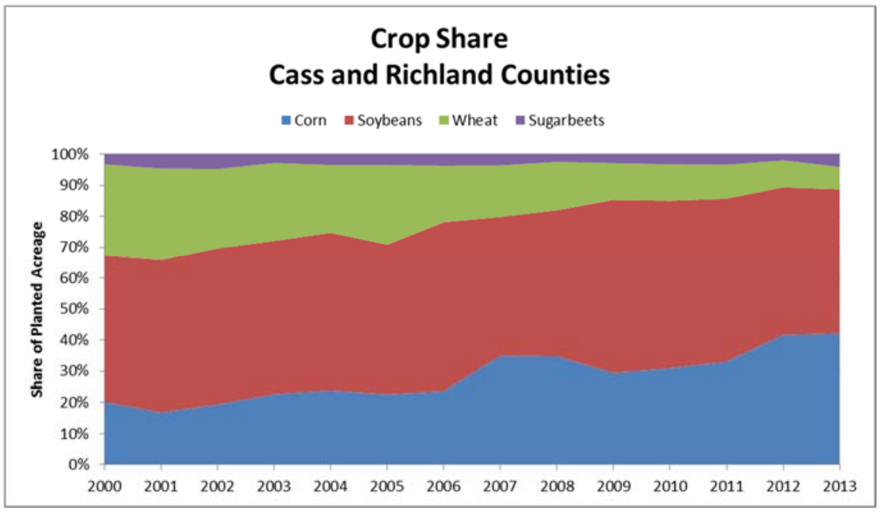

Figure 5. Relative Share of Corn, Soybeans, Wheat and Sugarbeet Acreage Cass and Richland Counties, North Dakota, 2000 through 2013.
Source: National Agricultural Statistics Service (2014).

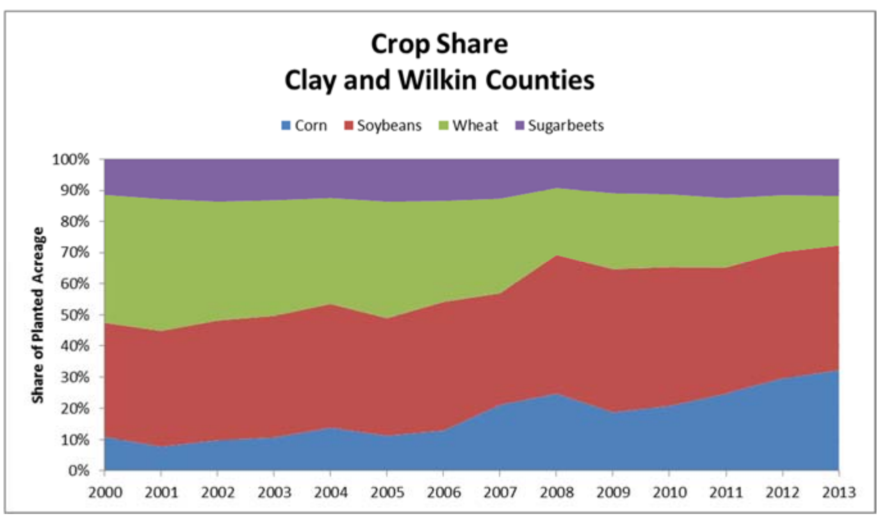

Figure 6. Relative Share of Corn, Soybeans, Wheat and Sugarbeet Acreage, Clay and Wilkin Counties, Minnesota, 2000 through 2013.
Source: National Agricultural Statistics Service (2014).

Table 4. Average Crop Share, Counties in FM Diversion Staging Area, 2011 through 2013				
	Minnesota Counties		North Dakota Counties	
Crop	Clay	Wilkin	Cass	Richland
	-------------------------------- % of Planted Acreage --------------------------------			
Corn	31.6	26.5	34.7	44.3
Soybeans	40.9	39.0	54.3	44.4
Sugarbeets	10.8	13.1	2.1	4.5
Wheat	16.7	21.5	8.9	6.9

Note: Crop shares estimated assuming 100 percent of planted acreage devoted to those four crops. Totals may not sum to 100 due to rounding.

<u>Crop Yields</u>

Crop yields were obtained from NASS (2014), North Dakota Farm and Ranch Business Management Program (NDFRBM) (2014), and Risk Management Agency (RMA) (2014). RMA and NASS estimates of crop yields for the study counties were similar, but NDFRBM estimates differed from both RMA and NASS data. NDFRBM data were not used because yields for the study counties came from a relatively small sample of producers and were not considered sufficient to represent crop production in the study region.

Considerable variability in annual crop yields for the four crops was observed in the NASS data (Figure 7). Crop yields per planted acre for each of the study counties from 2000 through 2014 were tested for fit to linear, quadratic and cubic regression models in an attempt to validate yield trends (Tables 5 and 6). No statistically valid (90% or higher threshold) trends were observed. The absence of statistically valid yield trends suggests a mean value would be appropriate for the study.

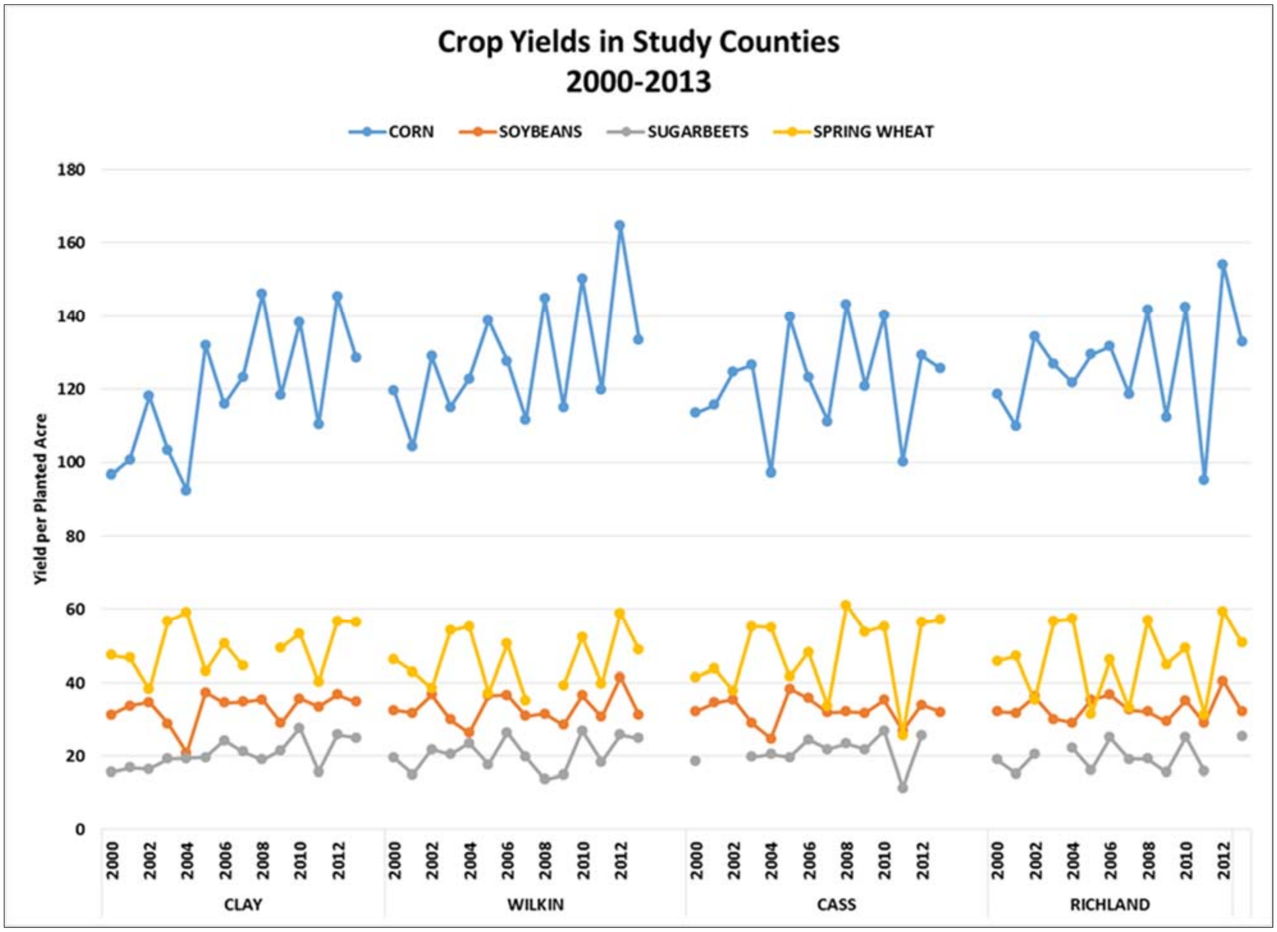

Figure 7. Crop Yields per Planted Acre, Clay and Wilkin Counties in Minnesota, Cass and Richland Counties in North Dakota, 2000 through 2013.

Source: National Agricultural Statistics Service (2015).

Table 5. Tests for Yield Trends, Wheat, Corn, Sugarbeets, and Soybeans, Clay and Wilkin Counties, Minnesota, 2000 through 2013					
County/Crop	Regression Model	Coefficient	Standard Error	t Value	Pr > |t|
Clay					
Wheat	Linear	0.09452	0.119	0.79	0.4475
	Quadratic	-0.01541	0.01833	-0.84	0.4222
	Cubic	0.000733	0.000813	0.9	0.3908
Corn	Linear	0.0229	0.09205	0.25	0.8086
	Quadratic	-0.00053	0.01401	-0.04	0.9704
	Cubic	-3.70E-06	0.000615	-0.01	0.9953
Sugarbeets	Linear	-0.01598	0.125	-0.13	0.9008
	Quadratic	0.006552	0.01903	0.34	0.7378
	Cubic	-0.00031	0.000836	-0.36	0.7228
Soybeans	Linear	-0.09878	0.1284	-0.77	0.4595
	Quadratic	0.01496	0.01954	0.77	0.4618
	Cubic	-0.00059	0.000858	-0.68	0.5097
Wilkin					
Wheat	Linear	0.09154	0.1497	0.61	0.5561
	Quadratic	-0.01817	0.02306	-0.79	0.451
	Cubic	0.000944	0.001023	0.92	0.3801
Corn	Linear	0.02365	0.09433	0.25	0.8071
	Quadratic	-0.00224	0.01436	-0.16	0.8792
	Cubic	0.000116	0.000631	0.18	0.8581
Sugarbeets	Linear	0.04351	0.1293	0.34	0.7435
	Quadratic	-0.00543	0.01969	-0.28	0.7882
	Cubic	0.000258	0.000865	0.3	0.7715
Soybeans	Linear	-0.02671	0.1057	-0.25	0.8057
	Quadratic	0.003128	0.01609	0.19	0.8498
	Cubic	-0.00009	0.000707	-0.12	0.9065

Table 6. Tests for Yield Trends, Wheat, Corn, Sugarbeets, and Soybeans, Cass and Richland Counties, North Dakota, 2000 through 2013					
County/Crop	Regression Model	Coefficient	Standard Error	t Value	Pr > |t|
Cass					
Wheat	Linear	0.1389	0.2105	0.66	0.5243
	Quadratic	-0.02111	0.03204	-0.66	0.5248
	Cubic	0.000929	0.001407	0.66	0.524
Corn	Linear	0.06633	0.08314	0.8	0.4435
	Quadratic	-0.00797	0.01265	-0.63	0.5427
	Cubic	0.000273	0.000556	0.49	0.6334
Sugarbeets	Linear	-0.09384	0.2176	-0.43	0.6793
	Quadratic	0.01752	0.03579	0.49	0.6395
	Cubic	-0.0009	0.001694	-0.53	0.6125
Soybeans	Linear	-0.03551	0.1032	-0.34	0.7378
	Quadratic	0.005181	0.0157	0.33	0.7482
	Cubic	-0.00023	0.00069	-0.33	0.745
Richland					
Wheat	Linear	0.04414	0.1934	0.23	0.8241
	Quadratic	-0.01031	0.02944	-0.35	0.7335
	Cubic	0.000571	0.001293	0.44	0.6684
Corn	Linear	0.1066	0.1039	1.03	0.3293
	Quadratic	-0.01557	0.01581	-0.98	0.3482
	Cubic	0.000663	0.000695	0.95	0.3625
Sugarbeets	Linear	0.06539	0.1602	0.41	0.6938
	Quadratic	-0.00939	0.02455	-0.38	0.7122
	Cubic	0.000424	0.001076	0.39	0.7035
Soybeans	Linear	0.01675	0.08702	0.19	0.8512
	Quadratic	-0.00275	0.01324	-0.21	0.8396
	Cubic	0.000138	0.000582	0.24	0.817

The issue of yield trends is somewhat dependent upon data. County-level published estimates of crop yields generally have less variability in yield trends than longitudinal data at the producer or farm level. Yield trends may be more apparent if producer-level data, representative of crop production in the staging area, were available. However, producer-level data were not available for this study.

An appropriate question is what yield should be used in the analysis. Historical crop yields reflect both planting conditions and seasonal growing conditions. Therefore, past yields may not be the most appropriate for estimating relative yield losses due to planting delays since those historical yields may already reflect less than optimal planting conditions, and most certainly include factors which occur after planting that affect yield.

The growing conditions after planting are assumed to be unrelated to the FM Diversion. An analysis of how past yields may be adjusted to account for all factors of production was considered beyond the scope of this study. Producers indicate that timing of planting is important as crops planted during optimal conditions generally are better able to capitalize on favorable growing conditions and also are generally more capable of withstanding unfavorable growing conditions, resulting in relatively better yields (NDSU Focus Group).

Yields from NASS were used as a starting point for estimating a target yield (Tables 7 and 8). Target yield would be the estimated or anticipated yield that agricultural producers strive to obtain and adjust the level of inputs and farm practices to achieve (e.g., fertilizer, seed rate, seed maturity, seed bed preparation). A target yield was used to estimate yield reductions from delayed planting. NASS yields were adjusted based on input from a producer focus group (Tables 7 and 8). Seven producers provided estimates of their target yields. The focus group participants indicated that target yields for producers in the staging area would be about 125 percent of the NASS yields (Tables 9 and 10).

Table 7. Crop Yields, Per Planted Acre, Clay and Wilkin Counties, Minnesota, 2004 through 2013

	Clay County				Wilkin County			
Year	Corn	Soybeans	Wheat	Sugarbeets	Corn	Soybeans	Wheat	Sugarbeets
	-------------- bu/acre --------------			- tons/acre -	-------------- bu/acre --------------			- tons/acre -
2004	92.4	20.8	59.0	19.4	122.8	26.3	55.2	23.4
2005	132.0	37.3	43.1	19.5	138.8	36.5	37.1	17.6
2006	115.9	34.6	50.7	24.2	127.7	36.6	50.6	26.4
2007	123.3	34.8	44.5	21.2	111.6	30.8	35.0	19.7
2008	146.0	35.3	na	19.0	144.7	31.5	na	13.6
2009	118.4	28.9	49.4	21.5	115.0	28.5	39.1	14.8
2010	138.4	35.6	53.3	27.5	150.3	36.5	52.4	26.9
2011	110.3	33.4	40.1	15.7	119.7	30.6	39.7	18.4
2012	145.3	36.7	56.7	25.8	164.6	41.5	58.9	25.8
2013	128.7	34.8	56.5	24.9	133.4	31.2	48.9	24.8

na=not available.
Source: National Agricultural Statistics Service (2014).

County average yields mask the variability that may exist during periods when spring planting has been delayed due to past flood events because a considerable amount of planted acreage in those counties is not subject to delays associated with spring flooding along the Red River or Wild Rice River. Yield data based on field-level production records or records from individual producers within the staging area would be more accurate than using county-level yields. However, field-level data were not available for this study.

Table 8. Crop Yields, Per Planted Acre, Cass and Richland Counties, North Dakota, 2004 through 2013								
	Cass County				Richland County			
Year	Corn	Soybeans	Wheat	Sugarbeets	Corn	Soybeans	Wheat	Sugarbeets
	------------- bu -------------			-- ton --	------------- bu -------------			-- ton --
2004	97.2	24.7	55.0	20.4	121.7	29.0	57.3	22.1
2005	139.6	38.3	41.5	19.6	129.4	35.3	31.5	16.2
2006	123.2	35.7	48.2	24.4	131.7	36.6	46.1	25.0
2007	111.1	31.8	33.6	21.7	118.6	32.5	33.1	19.1
2008	143.2	32.1	61.2	23.4	141.6	32.1	56.8	19.2
2009	120.9	31.8	53.8	21.7	112.3	29.4	44.8	15.6
2010	140.1	35.2	55.3	26.8	142.3	35.1	49.4	25.2
2011	100.1	26.9	25.6	11.3	95.3	29.0	31.2	15.8
2012	129.3	33.9	56.4	25.5	154.1	40.5	59.4	na
2013	125.6	31.9	57.1	na	132.9	32.1	50.8	25.3

na=not available.
Source: National Agricultural Statistics Service (2014).

Table 9. Target Yields, Per Planted Acre, Clay and Wilkin Counties, Minnesota								
	Clay County				Wilkin County			
	Corn	Soybeans	Wheat	Sugarbeets	Corn	Soybeans	Wheat	Sugarbeets
	------------- bu/acre -------------			- tons/acre -	------------- bu/acre -------------			- tons/acre -
NASS yield, Average 2011 - 2013								
	128.1	36.4	49.2	22.1	139.3	35.8	47.3	23.0
Average Target Yields obtained from Focus Group Participants								
	155.0	43.7	63.3	25.0	na	na	Na	na
Producer Target Yields as a Percentage of Three-year Average NASS yields								
	121.0%	120.1%	128.8%	113.0%	na	na	Na	na
Target Yields Used in the Study[a]								
	153.7	45.5	63.9	26.6	167.1	44.75	61.4	27.6

na=not available.
[a] Target yields estimated at 120% of NASS 3-year average yield for corn, 125% for soybeans, 130% for wheat, and 120% for sugarbeets.
Source: National Agricultural Statistics Service (2014); NDSU Focus Group (2015).

Table 10. Target Yields, Per Planted Acre, Cass and Richland Counties, North Dakota								
	Cass County				Richland County			
	Corn	Soybeans	Wheat	Sugarbeets	Corn	Soybeans	Wheat	Sugarbeets
	------------- bu/acre -------------			- tons/acre -	------------- bu/acre -------------			- tons/acre -
NASS yield, Average 2011 - 2013								
	118.3	32.1	44.6	18.4	127.4	35.2	45.3	20.5
Average Target Yields obtained from Focus Group Participants								
	148.7	41.8	63.5	27.5	155.0	45.0	na	Na
Producer Target Yields as a Percentage of Three-year Average NASS yields								
	125.6%	130.2%	142.5%	149.5%	121.6	127.9	na	Na
Target Yields Used in the Study[a]								
	142.0	40.2	58.0	22.1	152.9	44.0	58.9	24.6

na=not available.

[a] Target yields estimated at 120% of NASS 3-year average yield for corn, 125% for soybeans, 130% for wheat, and 120% for sugarbeets.

Source: National Agricultural Statistics Service (2014); NDSU Focus Group (2015).

Crop Prices

NASS crop prices represent statewide marketing-year average prices. A 7-year olympic average of North Dakota prices from 2008 through 2014 was used to represent commodity prices in the four-county study region (Table 11). Statewide prices received in North Dakota were used for storages areas in Minnesota and North Dakota.

Table 11. Statewide Average Marketing-year Prices, Minnesota and North Dakota, 2007 through 2014								
	Minnesota				North Dakota			
Year	Corn	Soybeans	Wheat	Sugarbeets	Corn	Soybeans	Wheat	Sugarbeets
	---------------- $/bu ----------------			-- $/ton --	---------------- $/bu ----------------			-- $/ton --
2007				45.20				46.30
2008	3.92	10.10	7.06	49.90	3.74	9.71	7.31	51.00
2009	3.47	9.39	4.72	49.80	3.18	9.26	4.82	51.90
2010	5.01	10.90	6.10	67.60	5.01	10.90	6.61	69.90
2011	6.09	12.40	8.06	68.30	5.81	11.90	8.24	60.80
2012	6.67	14.30	8.13	74.20	6.46	14.00	8.07	69.10
2013	4.30	12.90	6.68	52.60	3.91	12.40	6.62	44.90
2014	3.65	10.20	5.55	na	3.30	9.60	5.75	na
7-yr Olympic Average	4.59	11.30	6.69	57.64	4.35	10.90	6.87	55.82

Na=not available.

Source: National Agricultural Statistics Service (2015).

Historical Flood Events

Information on daily river heights and flow rates for the Red River in Fargo from 1940 through 2013 was obtained from United States Geological Survey (2014). While the Red River Valley has experienced a number of spring flood events since 1942, only nine events were of sufficient size in Fargo to have triggered the use of FM Diversion staging area (Figure 8); the flow in 1978 reached 17,000 cfs for one day and is not included in Figures 8 and 9. The current understanding is the staging area would operate with river flows exceeding 17,000 cubic feet per second (cfs). Historically, flood events with river flows exceeding 17,000 cfs in Fargo have occurred over a one-month period from about the third week in March to the third week in April. Five of the nine flood events have occurred during a one-week period from April 7th through April 13th.

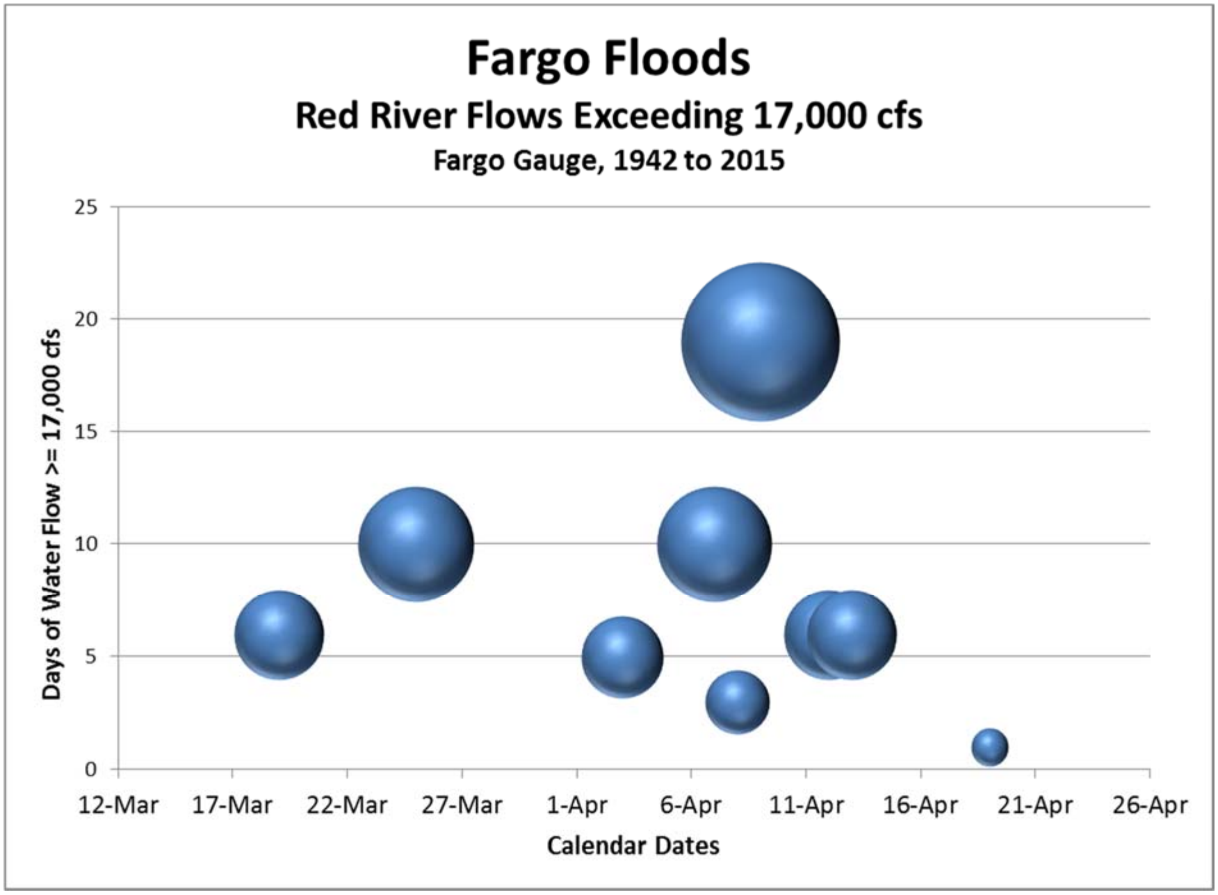

Figure 8. Relative Size and Calendar Dates for Flood Events in Fargo Sufficiently Large to Trigger Use of FM Diversion Staging Area, 1942 through 2014.
Source: U.S. Geological Survey (2014).

The timing of the flood events over the 1942 to 2014 period[6] shows that most of the large flood events have occurred in the latter part of the period (Figure 9). The frequency the region will

[6] The 1942 through 2014 period is largely consistent with the period of record used by the Corps in their evaluation for flood protection options for the Fargo/Moorhead metro area (U.S. Army Corps of Engineers 2011). The Corps period of record is from 1942 through 2009.

experience future flood events is not estimated in this study. This assessment does not predict how many large flood events will occur in the future in the Fargo/Moorhead area. Rather, the probability of a flood event occurring in any particular year is limited to the definition for flood sizes (e.g., 25-year flood event has a 4 percent chance of occurring in any given year). The definition of flood event size varies among Federal agencies[7].

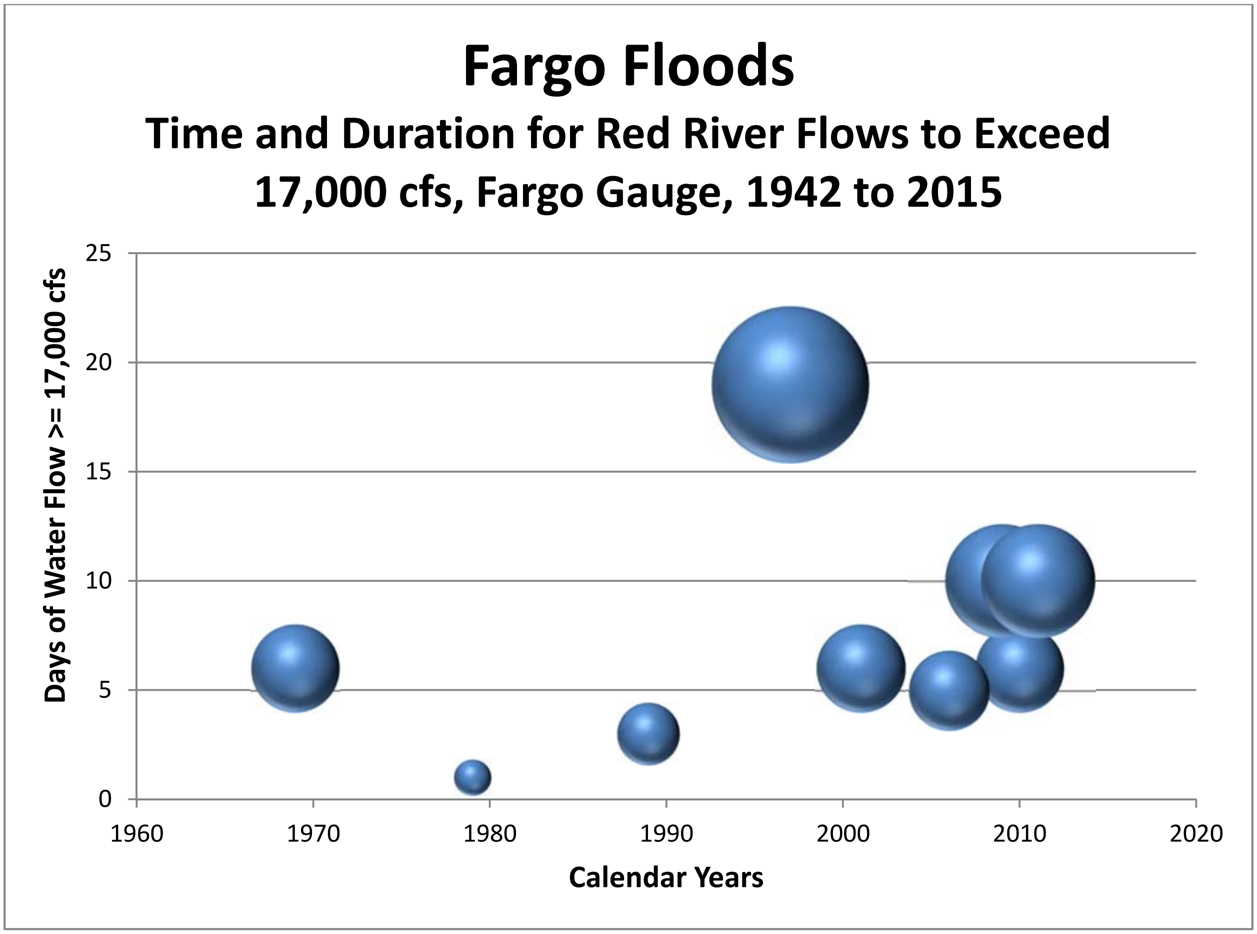

Figure 9. Year for Flood Events in Fargo Sufficiently Large to Trigger Use of FM Diversion Staging Area, 1942 through 2014.
Source: U.S. Geological Survey (2014).

Flood size will influence the use of the staging area and affect the duration of water storage on inundated lands. The effects of different-sized flood events are covered in the hydrology analysis conducted by the FM Diversion Authority (2015) (see section Hydrology Within Staging Area). The FM Diversion Authority modeling does not predict calendar dates of future flood events. The calendar date when a flood event occurs is important because it has direct effects on when the land will be available to plant.

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[7] U.S. Army Corp of Engineers and Federal Emergency Management Agency have different definitions of flood event size which is largely based on using different periods of record for flow data on the Red River (U.S. Army Corps of Engineers 2013).

Hydrology Within Staging Area

The FM Diversion Authority provided information on the expected hydrology associated with several flood event sizes for storage areas within the staging area for existing conditions (Without Diversion) and conditions anticipated With Diversion. The hydrology modeling was based on 10-year, 25-year, 50-year, 100-year, and 500-year synthetic flood events. The flood event sizes represent the annual probability or likelihood of a spring flood event reaching a certain size (e.g., crest height, volume of water flow). For example, a 100-year flood event has a 1 percent probability of occurring in any given year, and is a larger flood than a 25-year or 50-year flood event, which have a probability of occurring 4 percent and 2 percent in any given year, respectively.

The hydrology modeling was based a compilation of data to produce the synthetic flood events. The flood events were not necessarily reflective of a specific past flood. In addition to the five flood events, the FM Diversion Authority modeled a 1997-like flood event. The 1997 flood event represents an event where high flow rates were present in the Red River for longer periods than any other documented previous flood events, that is, flows exceeded 17,000 cfs for 20 days. The long duration of the 1997 flood event would provide a valuable contrast to the 2009 flood event. The 2009 flood event produced record crest heights in Fargo, but the flood event was of relatively short duration, that is, 10 days with flows exceeding 17,000 cfs (see Table 3 on page 5).

Hydrology modeling was provided for 98 storage areas within the staging area[8]. The 98 storage areas totaled 44,285 acres, but do not represent the total acreage within the staging area and do not match acreage estimates of the USACE-defined staging area. Data for each storage area included location, approximate elevation, size (acreage), water elevation over the course of a flood event, duration of water inundation (days), and time (days) for inundation to occur from when staging is initiated. Both Without and With Diversion conditions were provided for each storage area (see Appendix C).

Storage Area versus Land Inundated

Land associated With the FM Diversion can be measured by acreage actually flooded and acreage affected by flooding. In this study, *flooded acreage* represents land that will be submerged or inundated with temporary water and *affected acreage* represents the size of the storage area that contains flooded land (Figure 10). Due to varying elevations, the *acreage affected* by temporary water storage is likely to be greater than the acreage of land that temporarily holds flood water (Figure 10). Appendix C contains maps illustrating the *flooded acreage* within the 98 storage areas by size of flood event.

The economic analysis did not distinguish between the amount of flooded acreage within a storage area and the total acreage of the storage area. This study assumes any flooding within a storage area results in the entire storage area being affected. Flooding of land often affects access and/or use of adjacent or nearby lands. The extent or degree to which additional land is affected by flooding within any particular storage area will vary based on a number of factors. While this overall assumption results

[8] The U.S. Army Corps of Engineers' staging area is the portion of the upstream inundation area that contains the additional storage volume needed for project operation. The staging area consists of areas modeled with cross-sections as well as storage areas (see Figure 1 on page 2). Hydrology data for the cross-section areas are not included in this study.

in a conservative estimate of the acreage affected by temporary water storage, data to refine these assumptions were not available. Including all acreage of storage area that has some inundation does not influence the per-acre revenue losses estimated in the study.

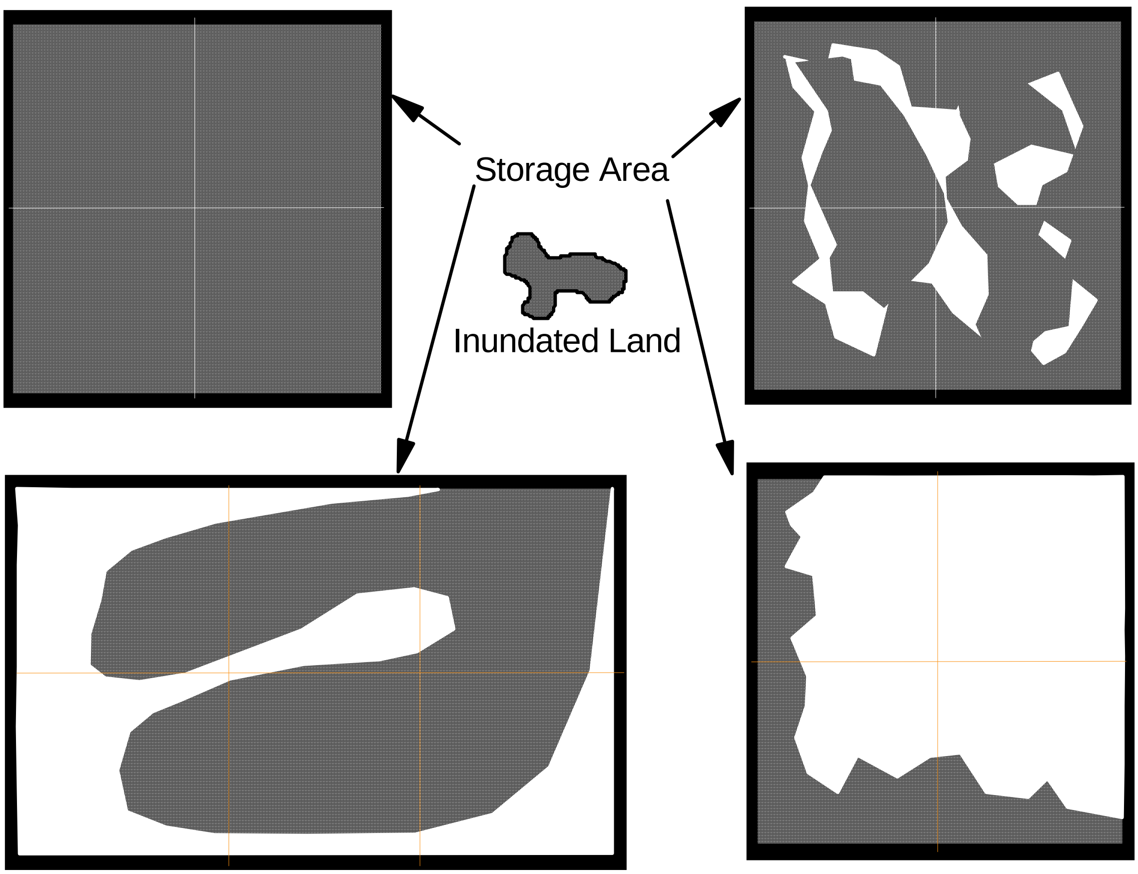

Figure 10. Conceptual Examples of Potential Land Inundation and Storage Area Size, FM Diversion.

Determining the extent that inundated acreage affects non-inundated acreage, from a production agriculture perspective, was beyond the scope of this study. Factors associated with accessibility (e.g., surrounding water prevents, blocks, or delays access to non-flooded land) and farmability (e.g., producer may choose to delay planting until all or a large majority of the acres are fit to plant even though not all acres were inundated) are covered by using the acreage of the entire storage area. Further evaluation of the hydrology, land accessibility, producer planting preferences, and land ownership within the staging area would be required to refine the amount of acreage not inundated but affected by temporary water storage.

Based on hydrology data provided by the FM Diversion Authority representing HEC-RAS 7.2 modeling[9], the acreage of land inundated with use of the staging area varies by frequency or size of flood event (Table 12). The hydrology modeling estimates the amount of acreage that would flood with the operation of the Diversion and acreage that would flood naturally with existing conditions. Very

[9] Hydrologic Engineering Center - River Analysis System, modeling version 7.2.

little additional flooding occurs within the staging area for a 10-year event With the Diversion. However for the other flood events, inundated acreage With the Diversion varies from about 16,600 acres for the 25-year event to 30,800 acres for the 500-year event (Table 12) (Appendix C). By contrast, under existing conditions about 6,100 acres would be naturally flooded with a 25-year event and 19,200 acres would be flooded with a 500-year event.

With a 25-year event With the Diversion, the engineering data estimate that 6,123 flooded acres would store water longer and 10,500 (16,647 minus 6,123) flooded acres would store water that otherwise would not store water. With a 50-year event, the Diversion would cause 8,220 acres to store water longer and 12,300 (20,513 minus 8,220) acres would store water that would not otherwise be inundated. Table 12 represents flooded acreage, but this study used affected acreage (i.e., all acreage within a storage area) as represented in Tables 13 and 14.

Table 12. Acreage Inundated by Spring Flood Events, by Flood Frequency, With and Without FM Diversion Staging Area

	Estimated Acreage of Land Inundated[a]		Percentage of Acreage Inundated[b]	
Flood Event	With Use of FM Diversion Staging Area	With Existing Conditions (no Diversion)	With Use of FM Diversion Staging Area	With Existing Conditions (no Diversion)
10-Yr	2,713	2,493	6.5	5.9
25-Yr	16,647	6,123	40.0	14.6
50-Yr	20,513	8,220	49.3	19.6
100-Yr	25,806	10,706	62.0	25.5
500-Yr	30,829	19,197	74.1	45.8

[a]Only acreage submerged by water.
[b] Based on acreage of 41,595 for project conditions and 41,915 for existing conditions, but does not include acreage of lands considered to be cross-section areas. Acreage affected by flooding will likely be greater than acreage of land inundated/flooded.
Source: FM Diversion Authority (2015).

Table 13. Total Acreage of Storage Areas affected by Spring Flood Events, by Flood Frequency, With and Without FM Diversion Staging Area

	Acreage of Storage Areas having Some Spring Flooding		Percentage of Acreage Affected[a]	
Flood Event	With Use of FM Diversion Staging Area	With Existing Conditions (no Diversion)	With Use of FM Diversion Staging Area	With Existing Conditions (no Diversion)
10-Yr	12,501	11,888	28.2	26.8
25-Yr	30,385	18,907	68.6	42.7
50-Yr	35,294	21,800	79.7	49.2
100-Yr	40,367	25,880	91.2	58.4
500-Yr	42,903	32,872	96.9	74.2

[a] Based only on the 98 storage areas encompassing 44,285 acres, as additional lands considered to be cross-section areas are not included in this study. Storage acreage not adjusted for With Diversion conditions (e.g., dikes, levees, embankments). Not all acres within storage areas will be inundated. Acreage of the 98 storage areas used in this study will not match acreage of the USACE-defined staging area.
Source: FM Diversion Authority (2015).

The hydrology modeling also can show if the duration of flooding changes for storage areas inside the staging area. The 10-year event had little difference in the duration of flooding based on acreage of affected storage areas inside the staging area; however, about 24,000 acres associated with storage areas would flood longer with use of the staging area in the 100-year and 500-year events (Table 14). In some cases, the duration of flooding would be less with use of the staging area due primarily to improved water flow as a result of the Diversion channel, modified culverts, or other features. About 3,000 acres with the 10-year event and about 5,000 acres with the 500-year event would experience a shorter flood inundation With the Diversion (Table 14). The other flood events had few acres that would flood for shorter periods With the Diversion compared to existing conditions.

Table 14. Difference in Storage Area Acreage affected by Spring Flood Events, by Flood Frequency, With and Without FM Diversion Staging Area

Flood Event	Acreage of Storage Areas Flooded Due to Use of Staging Area[b] (Group 5)	Change in the Duration of Water Inundation[a]		
		Storage Areas where Inundation is the SAME with Use of Staging Area (Group 2)	Storage Areas where Inundation is LONGER with Use of Staging Area (Group 3)	Storage Areas where Inundation is SHORTER with Use of Staging Area (Group 4)
	---- acres ----			
10-Yr	613	7,968	841	3,079
25-Yr	11,478	0	18,907	0
50-Yr	13,494	808	20,992	0
100-Yr	14,487	626	24,446	808
500-Yr	10,031	2,672	24,249	5,951

[a] Based on how many days flood water remains on the land.

[b] Only acreage of the 98 storage areas. Additional acreage is defined as the difference between total acreage inundated with the use of the staging area less acreage inundated naturally with no Diversion staging area. Not all acres within storage areas will be inundated. Acreage of the 98 storage areas used in this study will not match acreage of the USACE-defined staging area.

Source: FM Diversion Authority (2015).

Placing Hydrology Data on a Timeline

The most important element of the hydrology data for this study was to estimate how temporary water storage might affect spring planting. The hydrology data can be interpreted and used to describe different metrics for temporary water storage, such as days for the land to become inundated, days the land remains flooded, depth of inundation, and difference in time for water to leave the land between Without and With Diversion conditions.

The USACE and the FM Diversion Authority have evaluated and stated the hydrology data using the length of time that water remains on the land. For example in Figure 11, the storage area is flooded for 10 days Without the Diversion and 14.5 days With the Diversion. The net difference in time the land is flooded is 4.5 days. While that interpretation is accurate when describing the number of days storage areas are inundated, measuring only days of inundation are insufficient to estimate when the effects of flooding may be gone. In Figure 11, some of the 4.5 days of additional inundation occur earlier in the flooding period and some of the additional days extend the time the land would be flooded with existing conditions. Since a key assumption in this study is that the duration and depth of inundation do not change the time required for the land to dry out (e.g., dry-down is the same if water is on the land 5 days or 8 days or whether it is 1 foot or 4 feet), the important metric is the additional time required for the water to leave the land. In Figure 11, the additional days for water to leave the land is 3 days. However, knowing the additional days required for water to leave the storage area is still insufficient to estimate the effects on planting activities. *** *This study needed to place the hydrology data into a timeline*.***

To begin a timeline of effects relating to temporary water storage, the study used the activation of the staging area as the starting point. The number of days from when the Diversion is activated to when inundation occurs and the number of days flood water remains on the storage area was estimated from the hydrology modeling (Figure 11). These periods should not be confused with the number of days the land is inundated (i.e., metrics that have been previously used by USACE and FM Diversion Authority to describe the length of flooding).

Data from the hydrology modeling contain water elevations that are delineated into 12-hour increments. The length of time from when the staging area is activated until the water elevation exceeds the approximate field elevation[10] is measured by counting the number of 12-hour periods from the start of staging until the water elevation exceeds the storage area elevation. Once inundated, the length of time the storage area remains flooded can be estimated by counting the number of 12-hour periods that water elevation (i.e., flood waters) remains above the storage area elevation. The combination of those two periods provides an estimate of the total days from staging activation to when flood waters have receded from a storage area.

[10] The Approximate Field Elevation was obtained through a site specific elevation review (i.e., using LiDAR data) within each individual storage area. The intent was to identify the elevation at which the field would first become inundated with flooding. Given the complexity of representing the ever-sloping topography of an entire storage area (which may have a footprint upwards of a square mile or two) with a single elevation, the hydrology modeling used the lowest field elevation to represent the entire storage area. Ditch elevations also were identifiable using LiDAR data; however, ditch elevations were excluded in estimations of the approximate field elevation because they could retain water even though the field remains dry. Therefore, the lowest reasonable elevation, excluding ditches, was used as the Approximate Field Elevation (Houston Engineering 2015).

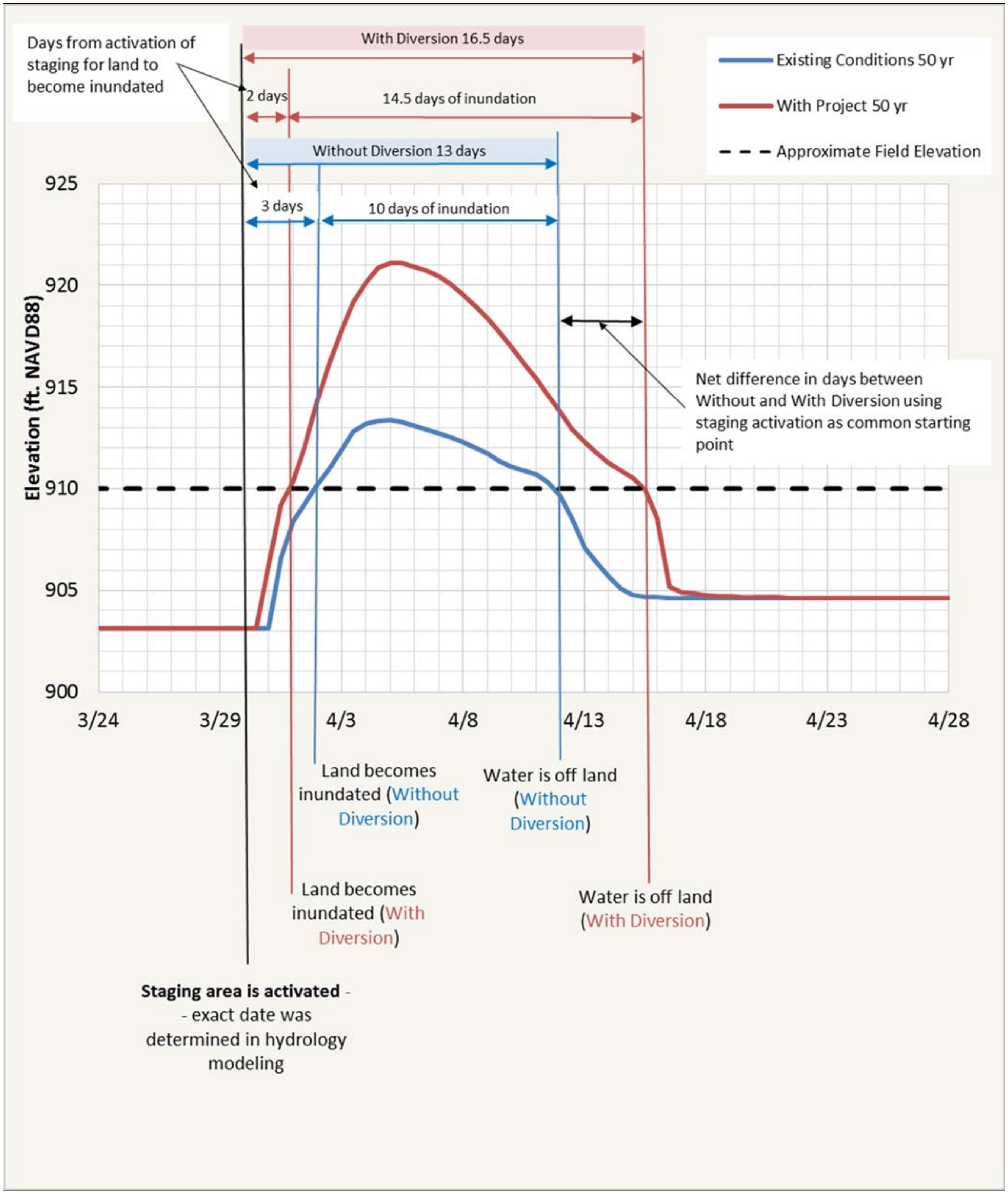

Figure 11. Placement of Hydrology Data in a Timeline, Sample Hydrograph for a Single Storage Area, 50-year Event, With and Without Diversion.

Source: FM Diversion Authority (2015).

Grouping Storage Areas into Common Hydrology Categories

Data from the hydrology modeling were used to estimate the difference between the existing conditions and conditions that would be expected if the FM Diversion operated the staging area. Some storage areas naturally flood within the staging area due to proximity or elevation relative to the Red River or Wild Rice River, depending upon size of the flood event. Other storage areas would not flood with existing conditions but the staging area would create conditions where those lands would flood. Therefore, the staging area can create three general outcomes: 1) no effect, as the land either does not flood or the amount of time the land is flooded remains unchanged, 2) land that would flood naturally Without the Diversion now floods longer or shorter due to the use of the staging area, or 3) land floods With the Diversion when that land would not otherwise flood. The hydrology data provided the basis where the effects of operating the staging area could be measured for each storage area.

A critical element in understanding the potential agricultural implications of short-term water storage on farmlands in the FM Diversion staging area relates to the duration or absence of water storage within the staging area. Understanding the hydrology differences between conditions Without the Diversion and conditions created by the FM Diversion, form the basis to evaluate the potential effects on spring field work.

The 98 storage areas comprising much of the FM Diversion staging area were grouped into five categories. Each category represents a different set of conditions between current hydrology and hydrology created by the FM Diversion with respect to spring flooding (Table 15).

- **Hydrology Group 1**: Storage areas that will not be flooded/inundated if the Diversion is operated. This outcome is due to land at a relatively high elevation in the staging area (*Does Not Flood*).
- **Hydrology Group 2**: Storage areas that will be flooded/inundated for the same duration whether or not the Diversion is operated; usually the lowest land in the staging area (*Floods the Same*)
- **Hydrology Group 3**: Land that will be flooded/inundated longer as a result of operating the Diversion (*Floods Longer*)
- **Hydrology Group 4**: Storage areas that will be flooded/inundated a shorter duration as a result of operating the Diversion because the features of the Diversion will drain the water away more quickly; however, the shortened storage time often is no more than a day (*Floods Shorter*)
- **Hydrology Group 5**: Storage areas that do not flood, but will be flooded/inundated With the Diversion (*New Flooding)*

The 98 storage areas will not necessarily be in the same hydrology group for all five flood event sizes. Flood event size determines which hydrology group a storage area represents. A storage area with a relatively low elevation (e.g., 909 ft msl) may be in Group 3 for most flood events, meaning it would flood With or Without the Diversion but floods longer With the Diversion. A storage area with a relatively high elevation (e.g., 925 ft msl) may be in Group 1 for most flood event events, meaning that it would not be inundated regardless of the Diversion. A storage area with a mid-elevation (e.g., 919 ft msl) may be in Group 3 during a large flood event, Group 5 in a moderate flood event, and Group 1 during a small flood event.

For agricultural producers, land contained within Hydrology Groups 3 and 5 are the only storage areas that incur adverse economic effects from the operation of the Diversion staging area and are likely to receive the greatest attention during policy discussions and debates. For most practical purposes, storage areas in Groups 1, 2 and 4 are not meaningfully impacted by the operation of the Diversion.

Table 15. Description of General Hydrology Conditions for Storage Areas Within the FM Diversion Staging Area

Hydrology Group	Description With Existing Conditions	Effects of the FM Diversion[a]
1	Does not flood	Does not flood
2	Already floods	Flood duration is unchanged
3	Already floods	Flood duration is longer
4	Already floods	Flood duration is shorter
5	Does not flood	Will now flood With Diversion

[a]The flooding effects of operating the Diversion do not necessarily imply all acreage within that storage area is inundated.

The timing and duration of water inundation varies considerably among the storage areas for each of the five flood event sizes. In the 10-year flood event, over 70 percent of the acreage as defined by the 98 storage areas is not inundated, whereas in the 500-year flood event only 3 percent of the acreage is unaffected (Table 16). Storage areas that either flood the same duration or flood with less duration With the FM Diversion (Hydrology Groups 2 and 4, respectively) comprise a minority of acres in all five flood event sizes. Storage areas in Hydrology Groups 3 and 5 (lands that are inundated longer or lands that flood as a result of the Diversion) comprise about 3 percent of the staging area in a 10-year flood but comprise nearly 89 percent of the acreage in a 100-year event. (See Appendix C for detailed information on the hydrology groups for the five flood events).

Table 16. Acreage of Hydrology Groups, by Size of Flood, Operation of the FM Diversion Staging Area

	10-year Event		25-year Event		50-year Event		100-year Event		500-year Event	
Group	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
1[a]	31,784	71.4	13,900	31.4	8,991	20.3	3,918	8.9	1,382	3.1
2[a]	9,121	21.4	726	1.6	808	1.8	626	1.4	2,676	6.0
3[a]	849	2.0	18,181	41.1	20,992	47.4	24,446	55.2	23,911	54.0
4[a]	1,918	4.1	0	0	0	0	808	1.8	6,285	14.2
5[a]	613	1.0	11,478	25.9	13,494	30.5	14,487	32.7	10,031	22.7
Total[b]	44,285		44,285		44,285		44,285		44,285	

[a]Group 1 represents land that does not flood With Diversion. Group 2 represents land that floods for the same duration. Group 3 represents lands that flood longer With the Diversion. Group 4 represents lands where inundation is shorter With the Diversion. Group 5 represents lands that now flood With Diversion would otherwise not flood. Not all acres within storage areas for Groups 2, 3, 4, and 5 will be inundated.
[b]Based on total acreage of the 98 storage areas. Acreage of the 98 storage areas used in this study will not match acreage of the USACE-defined staging area.
Source: FM Diversion Authority (2015).

The length of time from activation of the staging area until water leaves a storage area varies among the hydrology groups for any particular flood event, and also varies across the five flood event sizes for each of the hydrology groups (Table 17). For example, the average length of time from activation of the staging area until water leaves storage areas in Hydrology Group 2 (flood duration is the same) ranges from 4.5 days in a 25-year flood event to 18 days in a 100-year flood event.

Table 17. Days from Staging Activation until Water Leaves the Storage Area, Average of All Storage Areas Within Each Hydrology Group for Each Flood Event

Hydrology Group	10-year Event		25-year Event		50-year Event		100-year Event		500-year Event	
	WO	W	WO	W	WO	W	WO	W	WO	W
	days									
1	0	0	0	0	0	0	0	0	0	0
2	7.2	7.2	4.5	4.5	17.0	17.0	18.0	18.0	15.4	15.4
3	6.5	7.0	9.2	12.7	10.0	13.3	10.6	14.7	11.5	13.8
4	7.75	7.25	na	na	na	na	22.0	21.5	22.5	21.0
5	0	6.5	0	9.8	0	9.0	0	10.5	0	10.9

WO = Without Diversion and W = With Diversion.
Source: FM Diversion Authority (2015).

The study is only concerned with the difference in when water leaves the storage area between the Without Diversion and With Diversion conditions. The difference between the Without Diversion and With Diversion conditions, averaged across all storage areas within the hydrology group, varies from 0.5 days for Hydrology Group 4 in a 100-year event to 10.9 days for Hydrology Group 5 in a 500-year event (Table 17). In Hydrology Group 3, the net difference in time for water to leave the land ranges from 0.5 days in a 10-year flood event to 3.5 days in a 25-year flood event. The Diversion is expected to add less than 3.5 days for water to leave the land for Hydrology Group 3 in the 50-year, 100-year, and 500-year flood events. Hydrology Group 5 has the largest difference, with storage areas ranging from no flooding to having 9 to 10 days from staging area activation until water leaves the land in four of the five flood events (Table 17).

Table 17 represents the average of all storage areas within each of the five hydrology groups for each of the flood event sizes; some storage areas will experience longer periods for flood waters to leave while others within the same hydrology group will experience shorter periods.

*** *An important clarification is that some storage areas within certain hydrology groups will be inundated longer than storage areas in other hydrology groups, and that the classification of the storage areas is based on the type of effects created by the Diversion, not based on how long the water is on the land or how long it takes for the water to leave the land. For example, a storage area in Hydrology Group 2 that floods the same duration (e.g., 12 days Without and 12 days With Diversion) may be inundated for a longer period than a storage area in Hydrology Group 3 that now floods longer With the Diversion (e.g., from 8 days of inundation Without Diversion to 10 days of inundation With Diversion).* *** See Appendix C for detailed hydrology for all 98 storage areas.

The distribution of acres affected within the staging area varies between Minnesota and North Dakota, both in terms of hydrology impacts and flood event size (Table 18). A disproportionate share of acreage in Hydrology Group 5 (does not flood but floods With the Diversion) lies along the Minnesota side of the staging area. By contrast, a disproportionate share of acreage in Hydrology Group 3 (floods longer) lies on the North Dakota side of the staging area (Table 18). Additional information on acreage of storage areas, by county and duration of inundation, are detailed in Appendix C.

Table 18. Distribution of Storage Areas, by State, Size of Flood Event, and Hydrology Group

	Flood Event Size				
State and Hydrology Group	10-year	25-year	50-year	100-year	500-year
Minnesota	--------------- Total Acreage of All Storage Areas in Hydrology Group ---------------				
1 No flooding	18,931	9,414	5,419	1,276	0
2 Floods Same	2,289	726	0	0	0
3 Floods Longer	0	2,817	5,056	8,369	11,713
4 Floods Shorter	0	0	0	0	409
5 No Flood, Now Floods	0	8,263	10,745	11,575	9,098
North Dakota					
1 No flooding	12,853	4,486	3,572	2,642	1,382
2 Floods Same	6,832	0	808	626	2,676
3 Floods Longer	849	15,364	15,936	16,077	12,198
4 Floods Shorter	1,918	0	0	808	5,876
5 No Flood, Now Floods	613	3,215	2,749	2,912	933

Source: FM Diversion Authority (2015).

Dry-down Period

Inundated land needs time to dry after the water recedes. Although the time necessary for dry-down will vary based on temperature, wind, precipitation, soil type, fall tillage, and cloud cover, the study assumes that dry-down and clean-up (e.g., remove or disperse debris) will take 10 days after the water leaves the land. Ten days are added to all storage areas that have inundation for either the Without Diversion or With Diversion conditions. The only hydrology group where the additional 10-days of dry-down are the result of the Diversion is Hydrology Group 5. For all storage areas in Group 5, the Diversion creates a potential delay equal to the days from staging activation until the water recedes plus another 10 days for the land to dry out.

Hydrology Groups 2, 3, and 4 also will require a dry-down period before planting, but the dry-down period is not an impact attributable to the Diversion. For example, if a storage area floods for 8 days With the Diversion and floods for 8 days Without the Diversion (Group 2), the 10 days of dry-down would have occurred in the absence of the Diversion. Even in situations when the Diversion results in inundation that extends beyond inundation with existing conditions, the Diversion would be responsible for the additional days for the water to leave the land, but not the 10-day dry-down period.

By placing the hydrology data into a timeline and adding time required for the land to dry out, the study can begin to assess potential planting delays. *Total days* represents the sum of days for the land to become inundated, days the land is inundated, and a dry-down period. *Potential days of delay* in this study are defined as the difference between total days Without the Diversion and total days With the Diversion.

Three important issues with respect to understanding how the hydrology data are measured, used and discussed in this study include:

- *Total days* for a storage area are not equal to the days that the storage area is inundated. Total days is the measure from when the staging area is activated to when the effects of flooding are gone. Total days includes a dry-down period for all storage areas that have any flooding.
- The difference in Total Days between Without and With Diversion conditions represents the *potential days of delay*. However, it is important to understanding that potential days of delay do not necessarily equal actual planting delays.
- The metrics used to describe the hydrology effects in this study will not match the metrics used in previous reports by the USACE and FM Diversion Authority. The differences are that this study needed to create a timeline whereas previous public reports and presentations by the USACE and FM Diversion Authority discussed the duration of flooding.

Focus Group Discussions With Agricultural Producers

The research team conducted a focus group meeting with farmers and producers who may be affected by the staging area. Eighteen people attended, including a representative from the FM Diversion Authority, members of the FM Diversion Authority Agricultural Policy Sub-Committee, agricultural producers, and the NDSU research team.

The purpose of the focus group meeting was to solicit discussion and insight from agricultural producers on six key issues important to the study. The research team also sought insight from participants on any additional issues that might need to be included in the study or general concerns of producers.

The following points summarize insights gathered during the focus group session.

1. Dry-down Period. The consensus was that dry-down time of 10 days under good conditions would be an appropriate approximation. Naturally, dry-down time would be affected by weather conditions. Producers also indicated that dry-down in April is different than dry-down in May. It was suggested that April is generally dryer which would imply faster dry-down. In May, producers often experience more rainfall which extends the dry-down period.

2. Yield loss due to planting delays. Yields for some crops are more sensitive to planting date than other crops. For example, producers indicated that soybeans are not as sensitive to planting delays as other crops. Consensus was that a 5 percent yield decline per day for corn would represent a maximum yield loss, and that 2-5 percent was more typical. Wheat losses were estimated to be approximately a bushel per day. Declines would not be linear but rather exponential with greater losses per day the further away from optimal plant dates.

3. Planting Rate. Producers stated that if necessary, planting can be done very quickly! One producer said he completed planting in 8 days one year. However, it was recognized that those conditions are not representative of typical planting rates. The consensus was 7 days (in the field) per crop or roughly 21 planting days to plant all crops was a reasonable approximation. Also, members of the group noted that it is not very likely to get 21 consecutive planting days. Participants approximated that those 20-21 planting days generally occur over a 40-day (calendar) period. There were some inconsistencies in comments regarding planting rate. Some participants seemed to suggest that their planting rate was faster than 21 days.

4. Target Yields. Producers were somewhat hesitant to talk about their yields but they were willing to write down their individual yields confidentially. Prior to some of the producers providing their individual yields, it was suggested the RMA times 110 percent might be a good estimate. Another producer suggested RMA times 125 percent. One participant suggested using the t-yield used for crop insurance for beginning farmers, but others felt that would be too low. It was suggested that as far as the applicability of county level data, Richland County data may be more representative of the impacted (storage) area than Cass County data. Most of Richland County is more likely to represent conditions in the Red River Valley than Cass County. Cass County extends beyond the Red River Valley to the west, and includes crop land considered to be outside of the Red River Valley.

5. Planting Start Dates. Participants indicated that corn plant dates are approximately equal to the planting dates for sugarbeets. In the study area, it was generally agreed that plant start dates would lag the county-wide plant start dates by about 5 days. This lag was largely due to soil conditions in the study region. Planting dates for wheat in Minnesota may be an appropriate proxy for the impacted area as most of the wheat grown in Minnesota is in east central to north central Minnesota which would be similar to the study area. The group agreed that sugarbeet plant start dates are fairly representative of plant start dates and would provide a reasonable proxy for start plant dates for wheat and corn in the region.

6. Switch Crops Planting Dates. The initial statement regarding crop switch dates was that crop insurance greatly influences plant switch dates. There were some comments about recent or upcoming changes to crop insurance. There was consensus among the producers that switch decisions regarding wheat were less elastic due to the desire/need to have those acres part of a 4-year sugarbeet rotation. Producers indicated that they are not likely to switch their wheat acres even when planting dates are delayed beyond optimal. They also indicated that they would not be eager, willing or likely to switch from corn to soybeans. They stated that they would likely wait until June 1st before switching from corn to soybeans. A June 1st switch date was later than suggested by crop production and agronomy specialists.

7. Other Issues brought forward by participants of the focus group.

a. Debris Deposit. There was quite a bit of discussion on the impact of flood debris on the land. Debris deposits include crop residues, branches, logs and other miscellaneous deposits. Participants indicated the debris has to be removed or burned. In cases when the debris cannot be removed or burned, producers have been forced to rake the debris at fairly high speed. Debris and beach lines impact dry-down and often the land has to dry-down before they can get on the land to clean up debris. There was no discussion about trying to quantify how much time it would take to clean-up the debris and whether this task represented a potential additional delay to planting. This issue may warrant further study to quantify the physical effects.

b. Physical Effects on Soil from Water Storage. These topics also may require further study. There may be little physical research available to quantify these impacts.

i. Water Depth and Compaction. This issue was raised during the discussion that no one knows if there are physical effects on the soil, such as soil compaction as a result of greater depths of water. During conversations after the meeting, it was suggested that the issue of compaction as a result of water storage likely was not an issue.

ii. Soil Organisms. While there was little discussion during the meeting, this issue was mentioned as a potential physical effect on soil from water storage, especially if the water remains on the land for long periods.

iii. Erosion. Producers wondered whether there would be additional erosion as a result of the Diversion quickly collecting water on the land and then quickly draining the water away.

c. Timing of Seed Orders. Again, there was limited discussion on this topic. Producers indicated there could be impacts on seed orders if forced to plant different maturing crops due to planting delays. Producers often try to purchase seed well in advance of spring planting, often during the winter when it is discounted. Again, not much discussion and the effects were not well described.

Methodology

A combination of factors needs to be considered in evaluating the impacts of temporary water storage on agricultural production in the staging area (Figure 12) with respect to spring planting conditions. The key *physical* factors would include timing of flood events, frequency of flood events, duration of flood events, length of time land is inundated, dry-down period, planting start dates, and planting progress rates. Key *economic* factors include agronomically optimal planting periods, reductions in crop yields for acreage planted after optimal planting window, switch dates to stop planting a crop and shift remaining acreage to another crop, crop yields, prevent planting date on which planting for the season will stop and acreage will remain unplanted, and crop prices.

The analytical framework was divided into modeling the physical effects of temporary water storage and then evaluating the economic effects. Historical data were used to determine a distribution or range of values for flood event start times, planting start dates, and planting rates. The physical effects were then modeled using a simulation approach that generated 10,000 combinations of flood event start dates, planting start dates, and planting rates. Each of the 10,000 combinations represents a possible spring planting condition.

Each of the 10,000 combinations was applied to the five flood events and the two conditions of Without and With the Diversion for each of the 98 storage areas. The crop share, yields (including a decline in yields for late planting), and price were applied to calculate the economic impact of staging water.

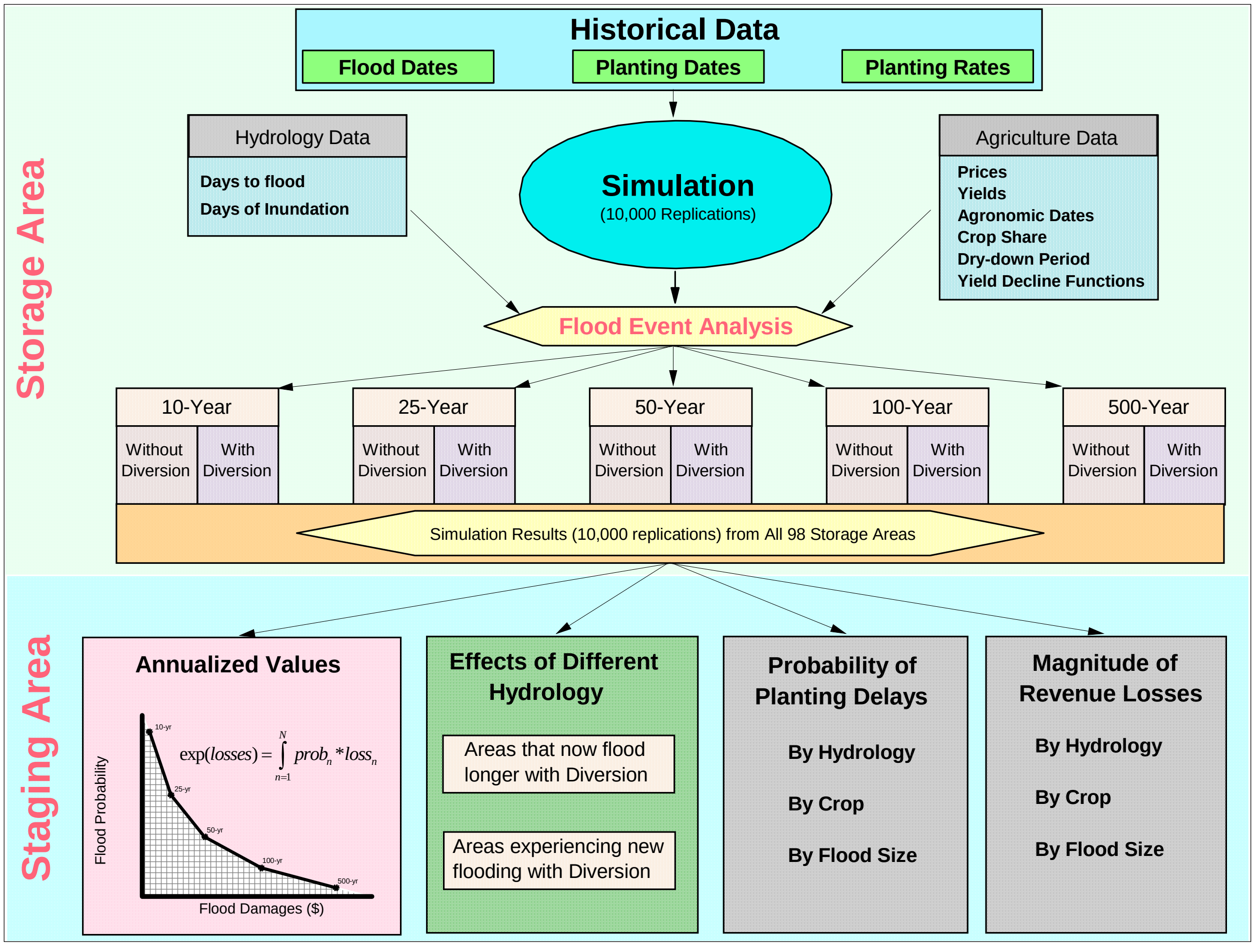

Figure 12. Flow Diagram for Simulation Analysis of Effects on Agricultural Production in the FM Diversion Staging Area.

The physical effects, such as size of flood event and duration of water storage, were derived from the hydrology modeling for each storage area. The analysis assumed future flood event frequencies were appropriately defined using the event-size probabilities associated with the hydrology modeling. *** *A 10-day dry-down period was used in all scenarios if a storage area was inundated regardless of the duration or depth of water*. ***

A set of producer decisions were developed that allowed the model to treat planting options consistently among the storage areas and across the 10,000 potential spring planting conditions. Optimal planting windows, switch dates, and “prevent planting” (do not plant) dates for wheat, corn, soybeans, and sugarbeets, in conjunction with planting rates, were used to calculation how many acres were planted during optimal conditions, how many acres were planted after optimal periods but prior to switch dates, how many acres were switched to another crop, and how many acres were “prevent planting” (land that is not planted that season due to delayed planting). The economic framework translated the combination of the physical effects into gross crop revenues for both the Without and With Diversion scenarios (Figure 12).

The methodology produced estimated gross revenues per acre for each storage area for current conditions (i.e., Without Diversion) and With Diversion conditions for each of the five flood event sizes.

The difference between the Without Diversion conditions and With Diversion conditions provided estimates of the effects of temporary water storage on gross revenues.

The economic effects for each flood event are associated with an annual probability of occurrence. The potential reductions in revenue associated with operating the staging area for a 25-year flood event represent the losses that have a 4 percent chance of occurring in any given years. Currently, the best manner to treat the frequency of when flood events occur is to define them based on the probability that they may occur during any particular year. The annual probability of occurrence and the amount or size of the flood event is determined or categorized based on historical climate, water flows, and other data (e.g., diking, channel constriction).

It would be incorrect to infer that the loss of revenue from any single flood event would be representative of the loss of revenue on an annualized basis. Flood events do not occur each year; therefore, the event-level economic effects must be combined with event-level probabilities. To produce an annualized expected revenue loss associated with the use of the staging area, a probability density function (PDF) was produced from the event-level values. The PDF represents a combination of the probabilities of occurrence and expected damages. It would, by default, also include zero losses for the annual probability that no flood event occurred. A mathematical technique that computes the integral of the PDF is then used to estimate annualized values.

Monte Carlo Simulations of Stochastic Variables

Monte Carlo simulation is an analysis method that can address risk when the conditions or issues require evaluation over a wide range of potential possibilities. Monte Carlo simulations can use cross-section, time-series or panel data. The technique uses a random selection of possible model inputs by 'pulling' a value from a statistical distribution of those inputs. The technique is therefore helpful in defining the frequency of possible outcomes and probabilities associated with those outcomes.

In this study, a statistical range of potential flood event start dates, regional planting dates, and regional planting rates were generated and used in a Monte Carlo simulation. An implied assumption is that the data used in this study are sufficient to represent a reasonable range of potential future outcomes. The accuracy of the Monte Carlo simulation is limited to the predictive capacity of the underlining data.

The statistical distribution of flood event start dates, planting start dates, and planting rates were assumed to be independent rather than jointed or conditional. For example, this assumption implies that the pace of spring planting is not a function of the flood event start date. In other words, a March flood event does not produce a slower planting season than an early April flood event or vice versa. In some cases, independent distributions may produce conditions that have a low probability of occurrence. For example, the distribution of flood event start dates and regional plant dates, over the past 15 years, have overlapped during the second week in April. There have been years when spring planting has begun at a time that would be equivalent to when a flood event was occurring in a previous year. To correct for potential problems with overlapping independent distributions, certain conditions were tested and adjusted within the model. The model will not allow a regional planting start date to precede a flood event start date.

Monte Carlo simulations also can use joint, conditional or multivariate statistical approaches, rather than independent distributions, when two or more variables are a function of other values in the analysis. Using joint, conditional, or multivariate distributions in this study would result in complex nested modeling due of two or more potentially linked conditions. Spring planting dates for land that does not flood would potentially require a different joint or conditional distribution with spring flood dates than lands affected by spring flooding. Considering the three distributions used in this study are all related to weather, estimation of the statistical links or causality among those variables would exceed the scope of this initial study.

An additional issue with statistical distributions is that applying assumptions of their predictive capacity from data that represents different sets of conditions can produce statistical anomalies when those distributions are combined into a single simulation. Such is the case with the lack of geographical specificity of the planting data. The study used statewide planting data on sugarbeets to represent starting times for corn, wheat, and sugarbeets since sugarbeets are primarily grown in the Red River Valley. However, the study used North Dakota statewide planting data for soybeans, which likely contains factors influencing planting progress that may not mirror conditions faced by producers in the Red River Valley within the same growing season. Since the sugarbeet and soybean planting data potentially represent combinations of factors than may not be reflective of both crops in the Red River Valley, the study used independent distributions. This approach resulted in a small number of planting conditions that were agronomically unlikely within the study region. However, applying alternative statistical techniques would not rectify the explanatory capacity present in the available data.

Statistical distributions of data can exhibit different shapes. A normal distribution of data resembles a bell shaped curve, suggesting an average value in the middle and approximately equal deviations on either side of the average value. This assumption is widely used in Monte Carlo simulations. With shorter data series and those with unknown probabilities, a uniform distribution is often used. A uniform distribution assumes an equal probability of occurrence of an event over a specific range or period.

Distribution of Flood Start Dates

U.S. Geological Survey (USGS) daily water flow data for Fargo for period of record was originally examined to produce a statistical distribution of flood event start dates based on dates when river flows peaked. Due to high variability with the flow data in non-flood years and difficulty in correlating the calendar dates of peak flows in non-flood years, actual calendar dates when the Red River equaled or exceeded 17,000 cfs were used instead of USGS daily flow data over the period of record to produce a distribution of flood event start dates.

The distribution of flood event start dates was assumed to be sufficient to model the approximate start date for use of the staging area. Actual use of the staging area will likely involve monitoring of gauge heights further upstream, and will likely result in the staging area being activated slightly sooner than suggested using dates that correspond with river flow levels in Fargo. The timing of the use of the staging area will be more defined when the operating manual for the Diversion is completed. The use of flood event dates for Fargo, as opposed to dates associated with river flows at gauges farther upstream, will result in the staging area being activated slightly later than may actually occur for any given flood event. Best estimates suggest the use of the Fargo flow data may delay, for purposes of this study, the triggering of the staging area by 1 to 2 days. A delay of 2 days or less was not perceived to materially alter the results of this assessment.

Dates for when the Red River equaled or exceeded 17,000 cfs in Fargo suggest an average flood date of April 5th (Figure 13). Over 70 percent of the time, the calendar dates for the flood start would fall between March 31st and April 10th.

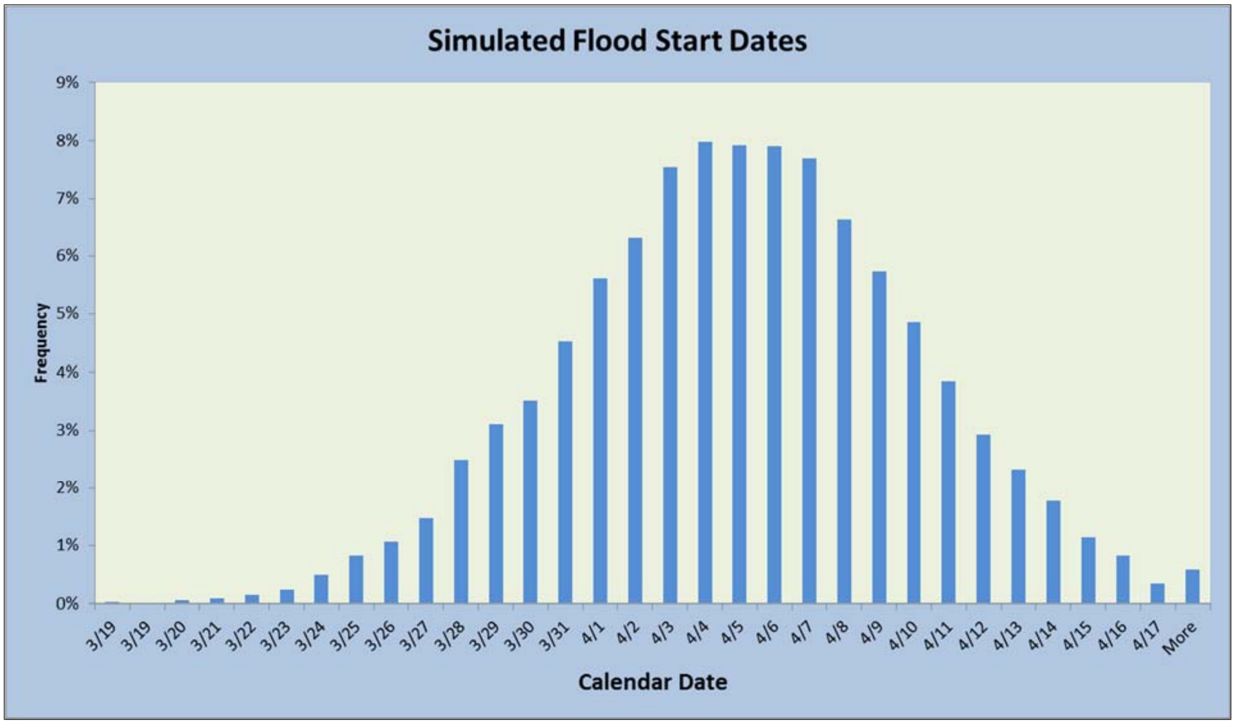

Figure 13. Monte Carlo Simulated Distribution of Calendar Dates When Red River Flows Would trigger use of the FM Diversion Staging Area.

Distribution of Planting Start Dates

The distribution of planting start dates for wheat, corn, and sugarbeets was based on NASS planting progress data for sugarbeets in North Dakota. Sugarbeets in North Dakota were considered the best proxy for start dates for corn and wheat since the progress data for sugarbeets was largely influenced by conditions in the Red River Valley, and producers traditionally begin planting wheat and corn at nearly the same period as sugarbeets. Producers in the focus group agreed, in the absence of better data, that sugarbeet planting progress data would be suitable for planting start dates for corn and wheat.

The planting start dates for sugarbeets in North Dakota were almost evenly distributed between April 14th and May 11th from 2000 through 2014, assuming a start date when 20 percent of crop acreage was planted (see Appendix A). A uniform distribution was chosen as the best representation of planting start dates for sugarbeets, corn, and wheat in the FM Diversion Staging Area (Figure 14). The distribution suggests any date from April 15th through May 9th has nearly an equal chance (4 percent) of being selected per replication.

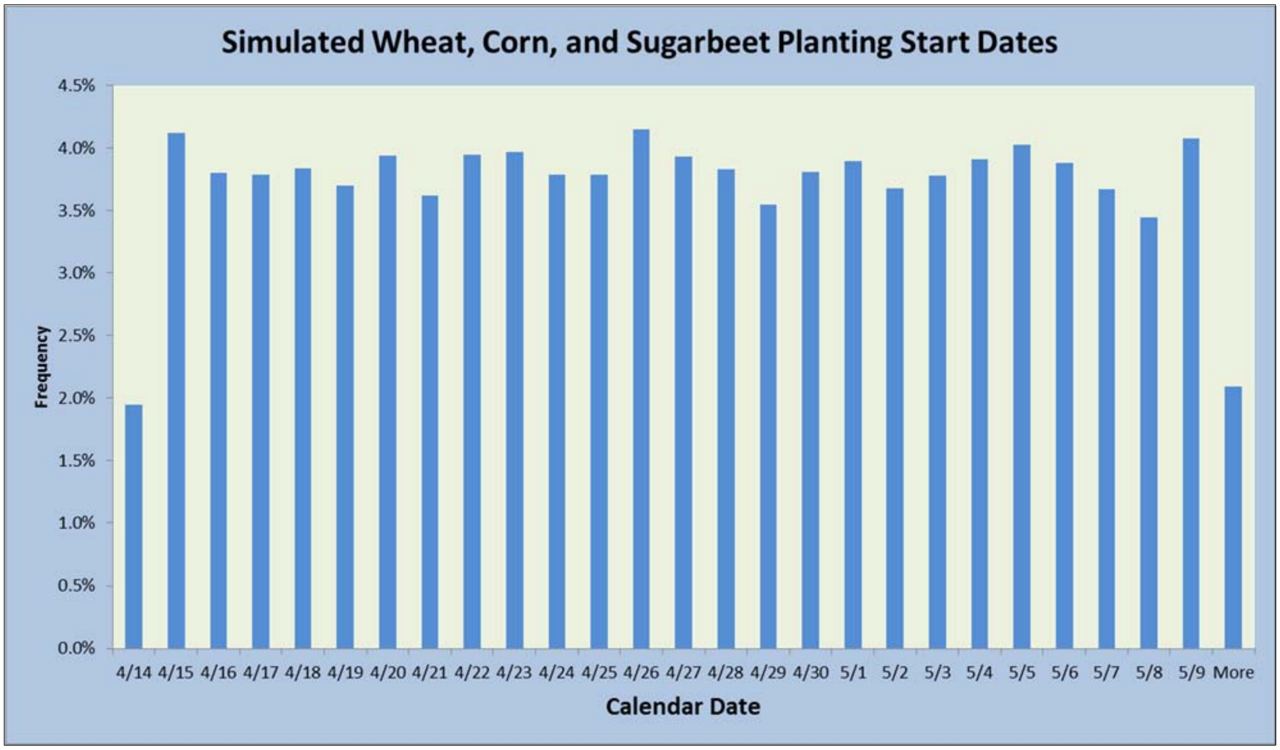

Figure 14. Monte Carlo Simulated Distribution of Regional Planting Start Dates, Wheat, Corn, and Sugarbeets, FM Diversion Staging Area.

The distribution of planting start dates for soybeans was based on NASS planting progress data for soybeans in North Dakota (see Appendix A). Unlike the planting start dates for sugarbeets, soybean planting start dates for North Dakota were clustered (i.e., 10 out of 15 years) from May 11th to May 19th. The NASS data for planting start dates for soybeans suggest the use of a normal distribution.

The distribution of soybean planting start dates ranged from May 1 through May 31. The highest likelihood for soybean planting start dates mirrored the NASS data, and around 75 percent of the replications would use a date from May 8th through May 19th (Figure 15).

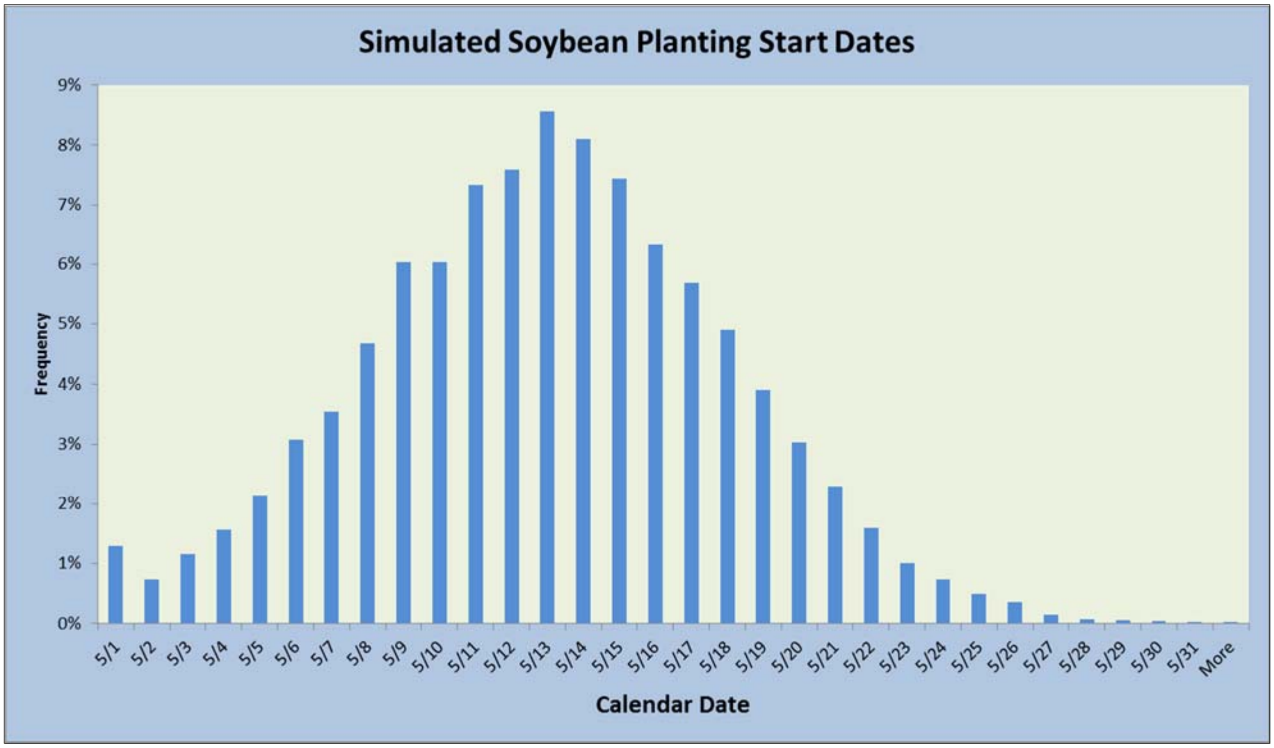

Figure 15. Monte Carlo Simulated Distribution of Planting Start Dates, Soybeans, FM Diversion Staging Area.

Distribution of Planting Rates

NASS data from 2000 through 2014, based on the rate of acreage planted per day from 20 percent to 80 percent of planting progress, was used to estimate the annual variability in planting rates. Separate estimates where generated for wheat, corn, sugarbeets and soybeans using planting progress data for North Dakota.

The typical time required to plant a crop was based on information gathered from agricultural producers. Producers indicated that increases in planting capacity have occurred in recent years, which may suggest that the planting rates for regional crops may exceed historical observations. Even though the regional rate of planting progress was adjusted to reflect current production capacities, the variability from year to year was retained when creating the distributions. The annual variability in the planting rates was considered to be reflective of the annual planting conditions (i.e., moisture, temperature) over the 2000 to 2014 period (see Appendix B).

The distributions of planting rates for the four crops are similar (Figures 16 - 19). Around 50 percent of planting conditions are represented by a planting rate of 6 percent to 8 percent of crop acreage per day over the planting season. A daily rate of 7 percent equates to approximately a 14-day planting period.

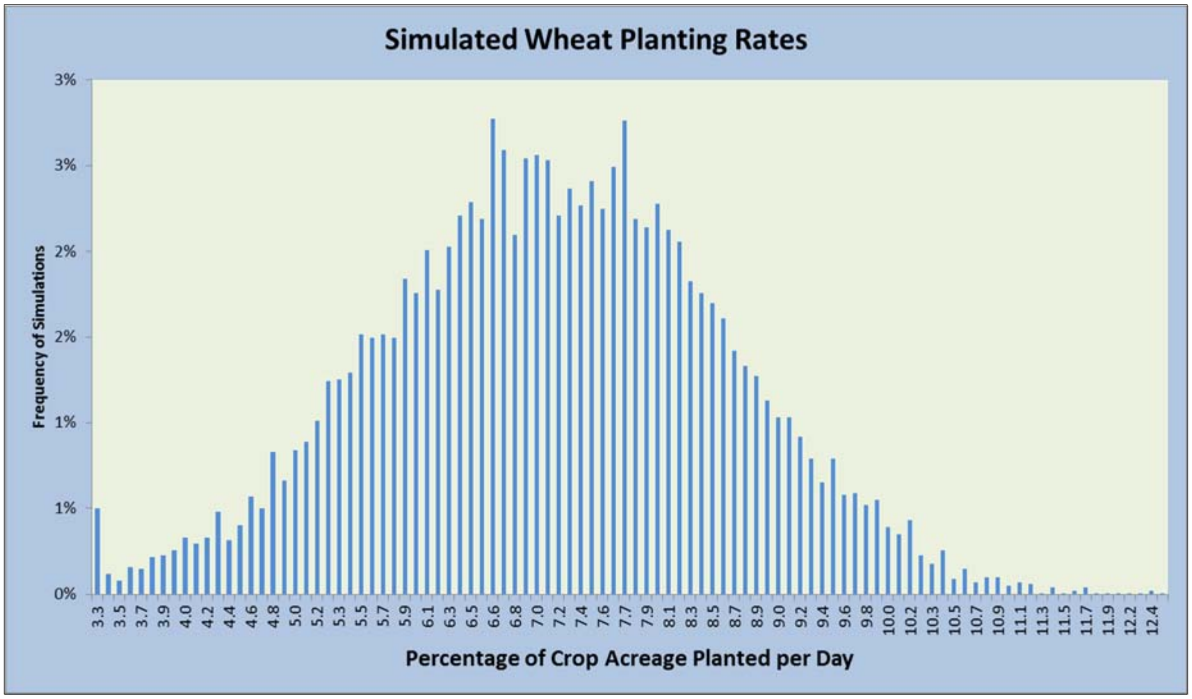

Figure 16. Monte Carlo Simulated Distribution of Average Seasonal Planting Rates, Wheat, FM Diversion Staging Area.

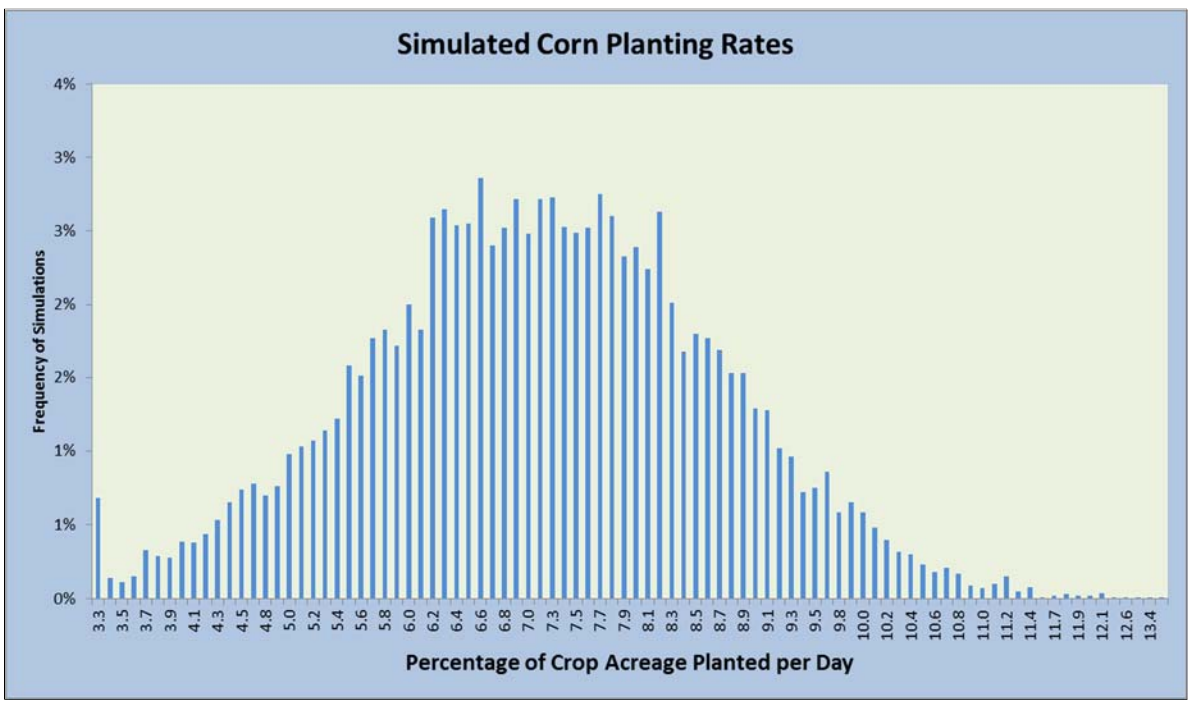

Figure 17. Monte Carlo Simulated Distribution of Average Seasonal Planting Rates, Corn, FM Diversion Staging Area.

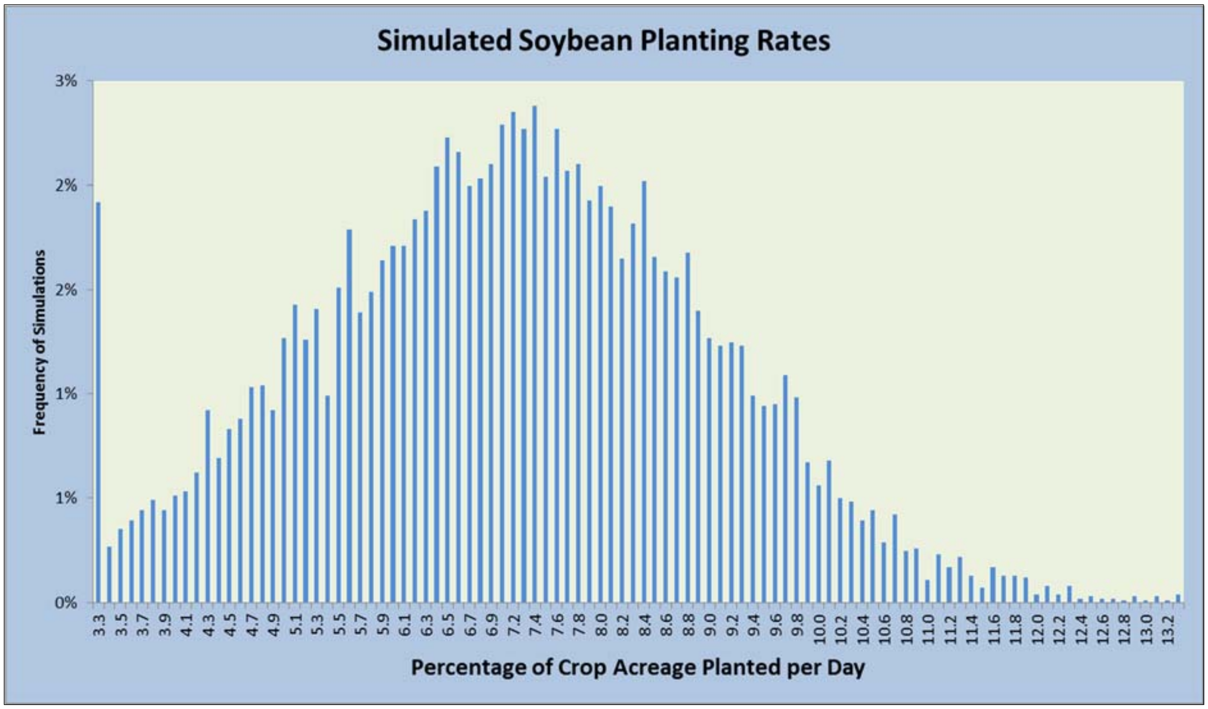

Figure 18. Monte Carlo Simulated Distribution of Average Seasonal Planting Rates, Soybeans, FM Diversion Staging Area.

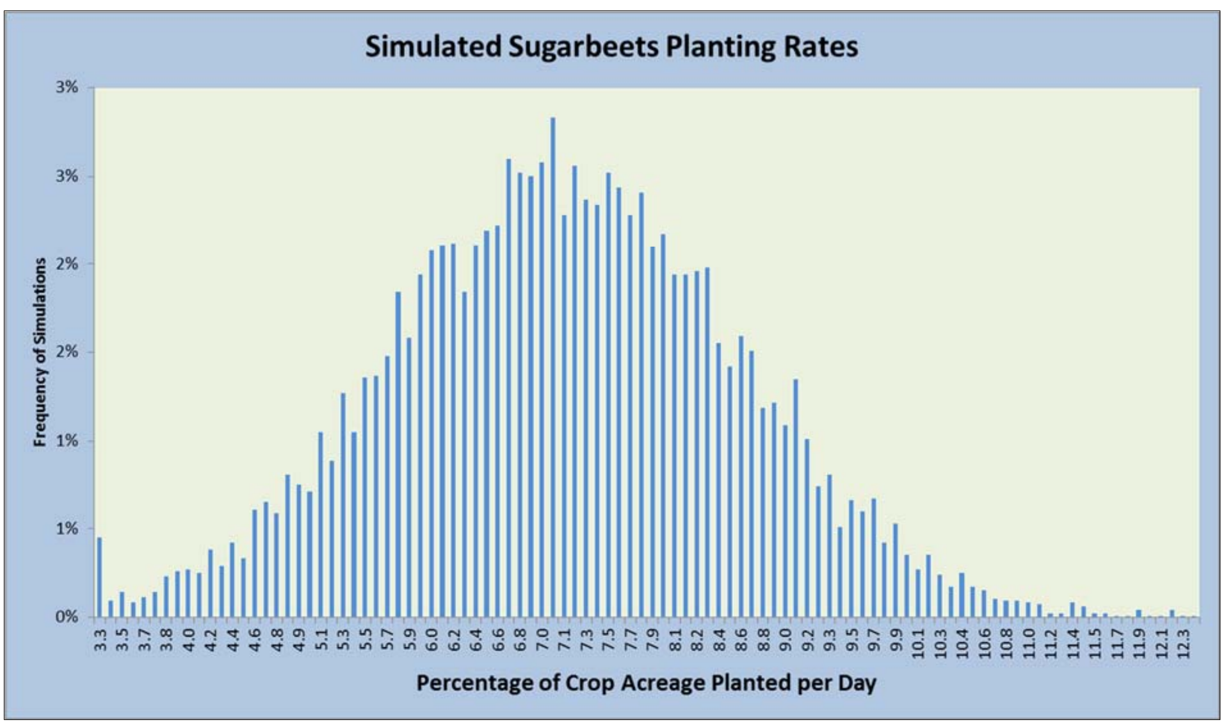

Figure 19. Monte Carlo Simulated Distribution of Average Seasonal Planting Rates, Sugarbeets, FM Diversion Staging Area.

Planting Framework

A modeling process was developed that chronologically traces key activities during the spring planting season for each of the 98 storage areas. The process starts with a flood event start date and works through the entire spring planting season. A series of planting decisions and producer actions were developed, specific to each crop and based on key agronomic dates, to narrow the range of producer behavior in flood years.

The first step was to combine start times for flood events (i.e., calendar dates from the simulations) with the hydrology modeling provided by the FM Diversion Authority (refer to Figure 11). The process works by estimating the number of days between activation of the staging area and when planting can occur (Figure 20). The potential time (i.e., days) from activation to when planting can occur will vary based on size of flood event and location of the storage area. A 10-day dry-down period is used on all storage areas that are inundated with current conditions or With Diversion conditions. For storage areas that are not inundated with flood water (either With or Without the Diversion), planting start dates are estimated using the simulated distribution of planting start dates (see section on Distribution of Planting Start Dates).

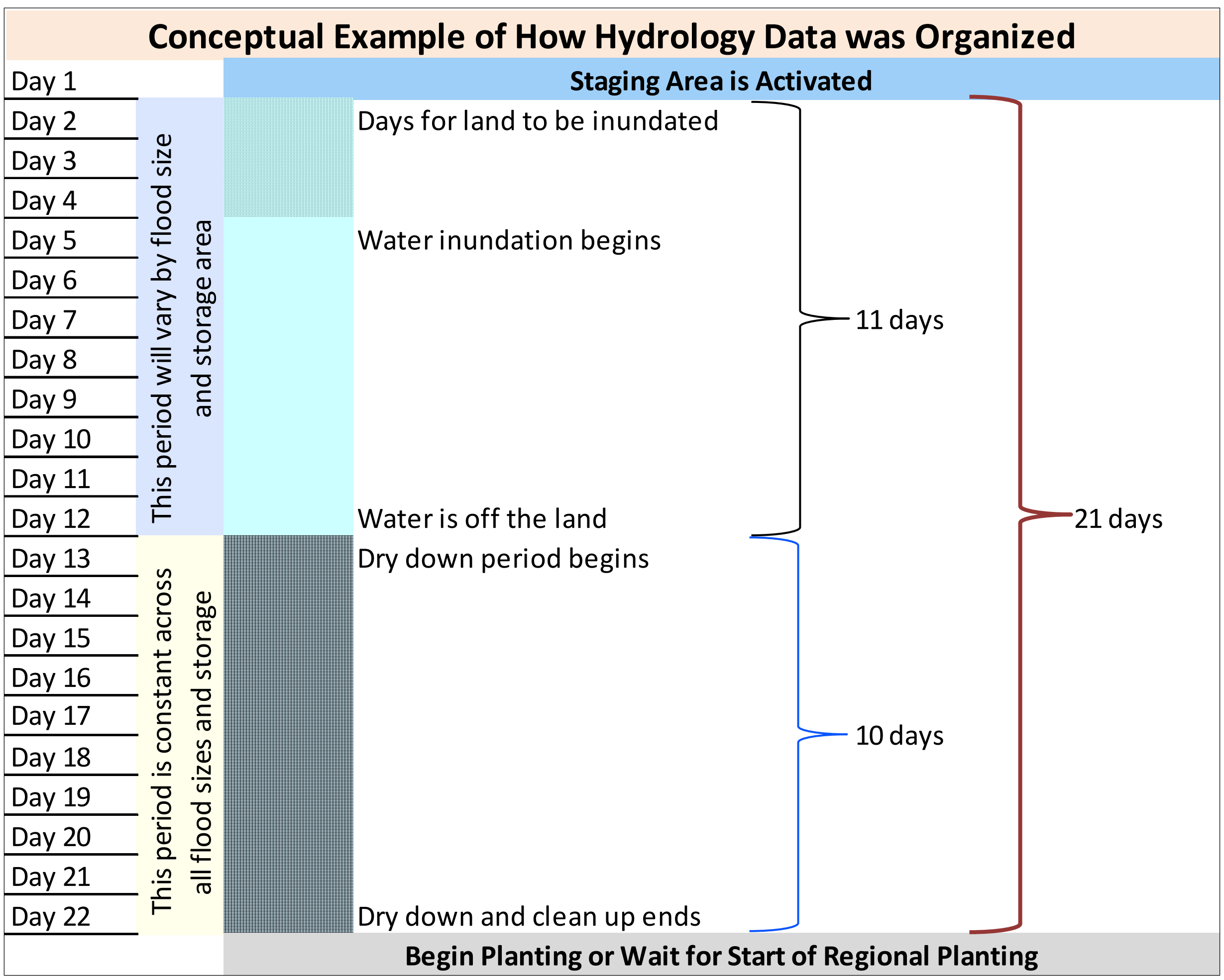

Figure 20. Example of the Analytical Framework of the Time Line from Activation of Staging Area to When Planting can occur for Storage Areas having Spring Flooding.

Each crop has an optimal planting period based on typical agronomic growing conditions throughout the year. If a crop is planted within that period, the producer generally has the best opportunity to realize maximum potential yields. Those opportunities are a generalization as each spring planting and subsequent growing seasons are different. Obviously, conditions in the spring and timing of when the crop is planted play an important role in crop yields, but a number of other weather-related factors also affect yields (e.g., temperature and precipitation throughout growing season, harvest conditions, wind or hail, summer flooding). For corn, timing of planting has been estimated to account for approximately 22 to 24 percent of the variability in yield trend departures from year to year (Nielson 2013). Stated alternatively, 76 to 78 percent of the yield variability is due to conditions unrelated to planting date.

This analysis focuses on estimating the effects of potential delays in spring planting due to temporary water storage on agricultural lands. As such, yields are assumed to be relative to the spring planting conditions, meaning that the yield obtained will be less than the yield that would have been obtained had the crop been planted during the optimal period. However, even with optimal planting conditions, yields are not likely to achieve maximum potential unless other factors throughout the growing season also remain favorable.

The model contains dates that correspond with agronomically optimal planting periods, switch dates to move unplanted acreage from one crop to another crop due to delays in planting, and "prevent plant" dates (Figure 21). The optimal planting dates were obtained from NDSU agronomy specialists (Ransom 2014b). Switch dates represent a consensus from discussions with agronomists, farm management specialists and producers (Ransom 2014b, Swenson 2014a; Aakre 2014, Olson 2014, NDSU Focus Group 2015). Prevent plant dates were obtained from Farm Service Agency (2015).

The analysis considers two possible dates for producers to begin planting and the model uses the latest of the following dates.

1) Spring planting start dates, based on historical data, when producers generally beginning planting.

2) Date when the land dries after spring flooding; those dates are based on spring flood start dates, size of flood event, and hydrology associated with the storage area.

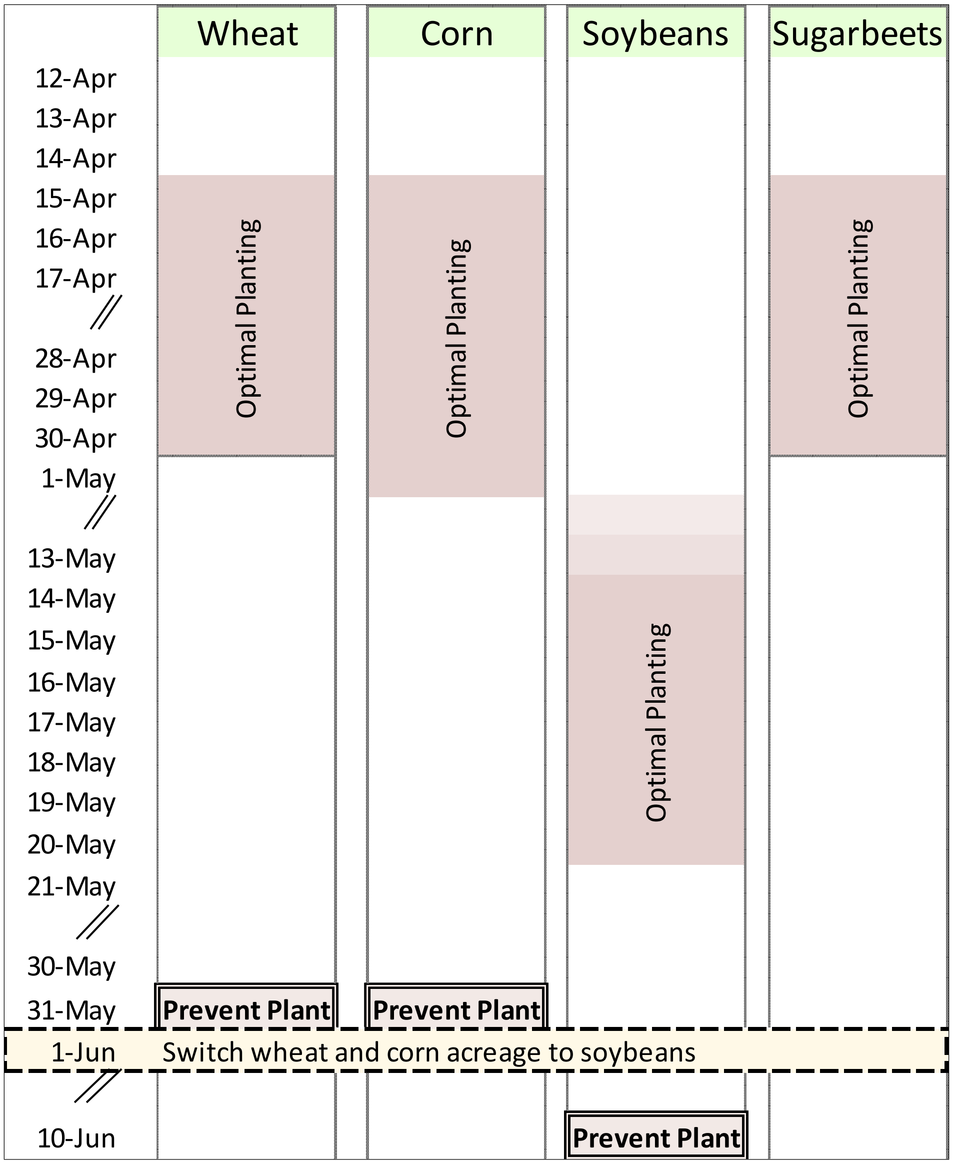

Figure 21. Optimal, Switch, and Prevent Plant Dates, Major Crops, Minnesota and North Dakota Counties in the FM Diversion Staging Area.

For example if planting in the region begins on April 10th, but due to flooding planting on a particular storage area cannot begin until April 15th, the model begins planting on April 15th for that storage area. Alternatively if the date when the storage area was expected to have dried out from flooding was April 8th (assume an early flood event of short duration) but planting in the region did not begin until April 12th, planting for that storage area would begin on April 12th.

Producers might experience numerous potential planting scenarios, depending upon flood start date, size of flood event, planting rates, and hydrology characteristics of the storage area. Figure 22 outlines potential combinations of planting start dates with agronomic dates. Six potential sets of planting circumstances were identified based on general dates when a producer may be able to begin planting. Those situations are identified below.

1) ***Producers would have no disadvantage in yields***—this situation is represented by the row labeled "A" in Figure 22. In this situation, the producer is not delayed in planting because the regional planting start date (shown as April 25th in Figure 22) occurs after the potential planting date suggested by the hydrology of the storage area. This condition would result in no difference between current conditions and With Diversion scenarios.

2) ***Producers are delayed in planting relative to the regional start date (April 25th in Figure 22), but producers are able to start planting within the optimal agronomic window for all crops***—this situation is represented by the row labeled "B" in Figure 22. In this situation, the producer would experience fewer days to plant during the optimal planting window relative to if they could have started planting on the regional start date. Depending upon the average planting rate that season, the effects of this planting situation may or may not have any bearing on acres switched to other crops or prevent plant acres.

3) ***Producers are delayed in planting relative to the regional start date and begin planting after the optimal planting window for all crops except soybeans***—this situation is represented by the row labeled "C" in Figure 22. In this situation, the producer would plant wheat, corn, and sugarbeets after the optimal planting window, and depending upon that year's planting rate, some wheat and corn acreage may be switched to soybeans or not be planted. Producers would still plant some acreage within the optimal window for soybeans.

4) ***Producers have missed the optimal planting window for all crops, but can begin planting prior to prevent plant dates for all crops***—this situation is represented by the row labeled "D" in Figure 22. In this situation, there is increased likelihood that some corn acreage will be switched to soybeans and/or not planted. A similar situation exists for wheat, except some wheat acreage might still be planted past the prevent plant date if that acreage is needed for a sugarbeet rotation. All soybean acreage planted would have reduced yield potential. Some soybean acreage may not be planted prior to the prevent plant date. Sugarbeets would be planted but with a substantial yield reduction.

5) ***Producers have missed the "prevent plant" deadline for wheat and corn, and have limited days to plant soybeans before the "prevent plant" deadline***—this situation is represented by the row labeled "E" in Figure 22. Sugarbeets could be planted but at a substantial yield reduction. All wheat and corn acreage would be placed into prevent plant. Some soybean acreage would be planted up to the prevent plant deadline, and any unplanted soybean acreage at that point would be not planted.

6) ***Producers have been delayed to the extent that no planting could begin prior to the prevent plant deadlines for wheat, corn, and soybeans***—this situation is represented by the row labeled "F" in Figure 22. Sugarbeets would be planted, but would produce a considerably reduced yield. All acreage for wheat, corn, and soybeans would be not planted.

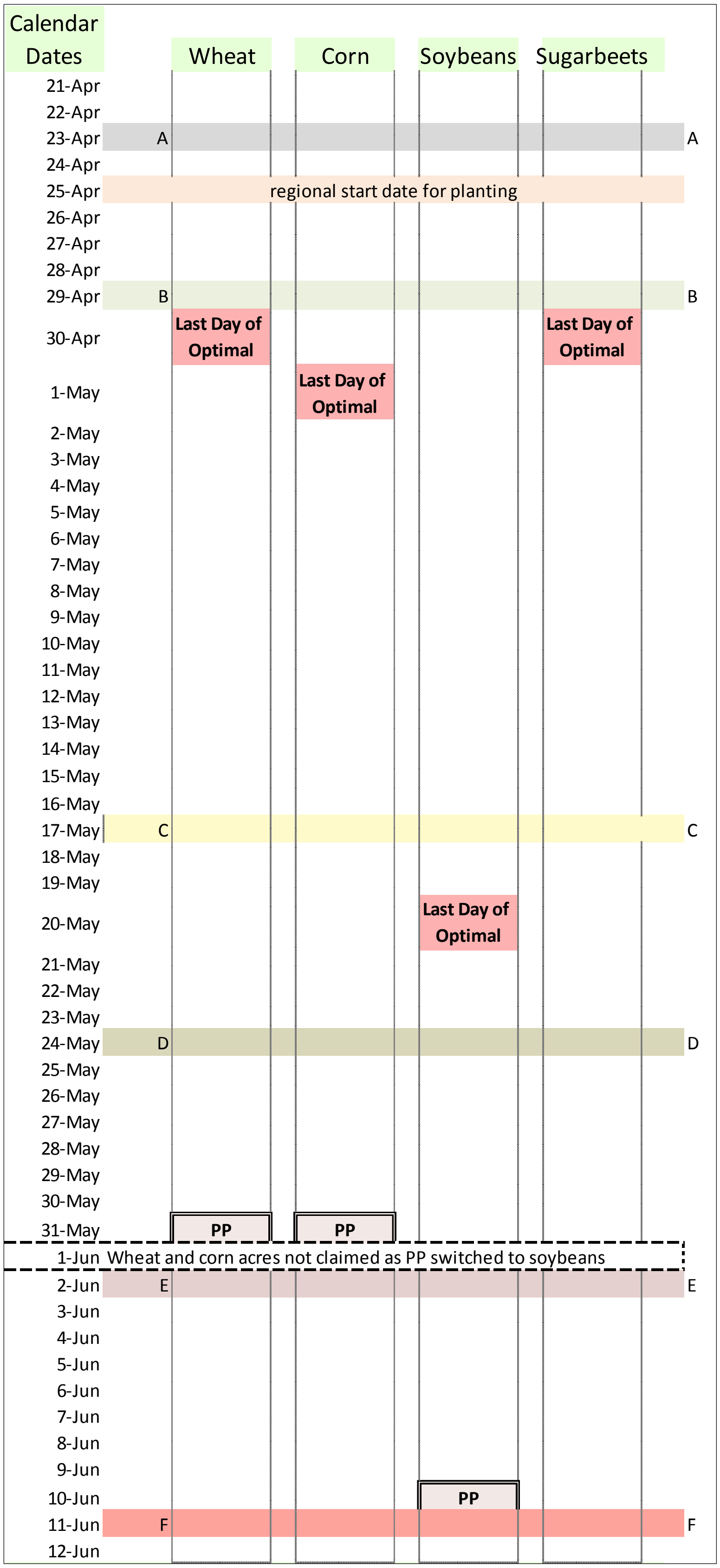

Figure 22. Outline of Planting Decisions based on Potential Planting Start Dates.
***PP** refers to Prevent Plant Date.

Allocation of Acreage between Prevent Plant and Switching Crops

The model does not estimate the producer-level economics to determine if the producer would be better or worse off by claiming prevent plant versus switching wheat and corn acreage to soybeans (see Appendix E for an example of a NDSU Extension decision tool addressing those issues). Economic criteria for those types of planting decisions would vary depending upon insurance coverage levels, past APH yields, potential future implications for changes to the APH, crop price, and individual producer expectations for profitability of switching acreage. Since producer-level profitability is not included in the analysis, nor are prices allowed to vary over the simulated replications, the programming requirements to include those decision criteria clearly exceeded the scope of this study.

Including producer-level economics within the model to guide acreage allocations to prevent planting versus switching to another crop would improve the analysis. However, the omission of those criteria in the modeling process was not considered a major concern for this study. The treatment of planting decisions was applied equally between the Without and With Diversion scenarios.

Current economics favor planting a crop rather than claiming prevent plant (Swenson 2014a, Aakre 2014). Producers at the focus group meeting also commented to the same current conditions (NDSU Focus Group 2015). However, those economics vary from year to year and among individual producers. Acreage claimed by producers as prevent plant varied considerably from 2009 through 2014 in the counties comprising the FM Diversion staging area (Appendix D). Although Farm Service Agency reports prevent plant acreage, the acreage reported as prevent plant does not necessarily mean all of those acres were idled that season (Olschlager 2015). Crop insurance has provisions where land can be claimed as prevent plant (e.g., corn) but may still be planted to another crop (e.g., soybeans). However, the payments and stipulations for planting a second crop differ from the payments when claiming a prevent plant condition and not planting a second crop. The stipulations on claiming prevent plant and planting a second crop currently make that option unattractive to most producers. The producer also could elect to plant acreage that was unsuitable to plant to their first crop choice and place that acreage into another crop without claiming prevented planting.

The analysis used a basic assumption that 20 percent of the land for wheat, corn, and soybeans that was unplanted as of the prevent plant deadline would be treated as prevent plant. The other 80 percent of that acreage would be shifted to another crop. The options for wheat and corn were to shift that acreage to soybeans. Unplanted acreage of soybeans after the prevent plant deadline was allocated to prevent plant and considered idled for the growing season.

Economic Variables

Storage areas in the staging area are assigned the percentage of wheat, corn, soybeans, and sugarbeets grown in the respective county (see Table 4). A three-year average was used to estimate the crop shares. By assigning some wheat, corn, soybean, and sugarbeet acreage to each storage area, the analysis does not have to distinguish among which crops would be raised on the storage area in any given year. The process also treats planting activities equally among all the storage areas, and does not suggest that storage areas close to the river or prone to flooding will only raise one crop and all the storage areas at higher elevations will only raise another crop.

An important component in the analysis is the variability in spring planting conditions. The rate of planting progress is based on a combination of historical data and information obtained from producers, and is represented by the percentage of acreage planted each day, averaged over the planting season. The planting rate in any particular season is based on the simulated distributions of planting rates. The planting rate is then used across all crops for the entire planting season. Planting rates are assumed to be consistent across crops (i.e., the planting rate for wheat is not different than the planting rate for corn) within a planting season. For example, early spring planting conditions for corn and wheat may be slow due to cool temperatures and/or moisture. However, those conditions may change by the time soybean planting begins. Of course, the reverse situation also is possible as conditions may be more favorable early in the planting season than later in the planting season.

Yield Losses

During non-optimal planting periods, the analysis uses a daily yield reduction over the spring planting period. For example if a crop is likely to have a 1 percent yield loss for each day of delayed planting, yield on the first day following the last optimal planting date for acres planted that day would be 1 percent less than the target yield. Acres planted on the second day following the optimal planting window would receive a yield 2 percent less than the target yield. The analysis continues with daily yield reductions until planting for that crop is completed, switched, or results in prevent plant.

-) Sugarbeets

Data were collected from several sources to evaluate the likely yield losses associated with delayed planting for sugarbeets (Cattanach et al. 1991; Dexter 2015; Metzger 2015; Peters 2015). The most frequent estimate of yield loss was 1.5 tons per acre per week. Evaluating the Minn-Dak Farmers Cooperative data revealed a yield loss of 1.43 tons per acre per week from May 6th through June 24th over the 2000-2014 period (Metzer 2015). The yield loss over that period was primarily linear. Based on those sources, the study used a yield loss rate of 1 percent per day for sugarbeet acreage planted after May 1st.

-) Soybeans

Data from the University of Minnesota, Crookston indicates that soybean yield reduction due to planting delays is relatively low from May 10th through June 10th but yield losses increase substantially throughout the rest of June (Figure 23) (Severson 2014). Producers attending the focus group meeting also indicated that yield loss due to delayed planting for soybeans was relatively minor until well into June. While the yield loss curve based on University of Minnesota data is not linear from May 19th through June 30th, a linear rate of 0.5 percent per day results in similar yield losses from May 10th through June 10th (Figure 23). Kandel (2015) acknowledged that the University of Minnesota, Crookston data are appropriate for estimating yield losses in the southern Red River Valley. Any acres of soybeans not planted by June 10th were assigned to prevent plant, therefore yield losses were not modeled after that date.

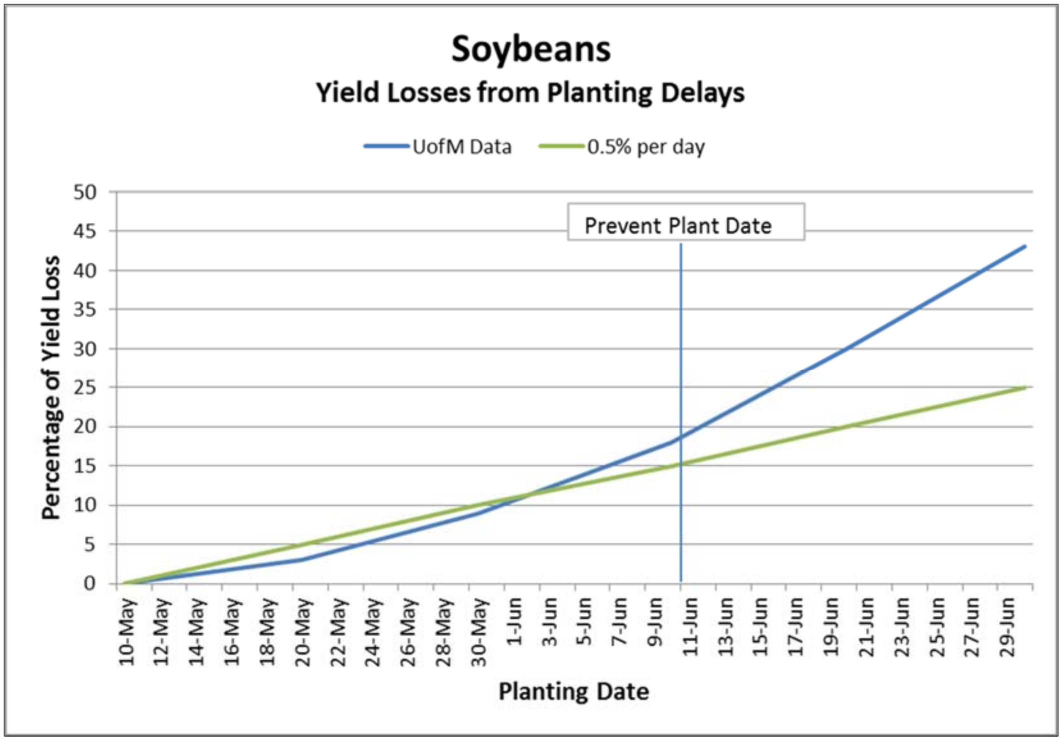

Figure 23. Yield Response to Delayed Planting, Soybeans, Red River Valley.
Source: Severson (2014).

-) Corn

Yield response from delayed planting for corn is well-documented in the Corn Belt producing region of the United States (Nafziger, E. 2008, 2011, 2012; Van Roekel and Coulter 2011; Myers and Wiebold 2013; Thomison and Geyer 2013; Doerge et al. 2015). Despite the widespread discussion of declining corn yields associated with delayed planting of corn, few articles directly address the issue of yield reduction for growing regions in North Dakota.

In southern Minnesota, Van Roekel and Coulter (2011) found that corn yields declined from 18 to 30 percent when planting was delayed by 4 weeks. They also found that it was not likely that producers could increase plant density (i.e., corn plants per acre) to offset economic losses from late planting. Coulter (2015) indicated optimal planting dates range from late April to early May in central to southern Minnesota, and suggested corn yields are likely to decline by 16 percent if planting is delayed until early June. Doerge et al. (2015) indicated that corn yield in the northern Corn Belt region declined about 35 percent when planted 6 weeks past optimal dates. However, yield losses over the six-week period were not linear. Northern Corn Belt was defined to include northern Iowa, southern and central Minnesota, southeast South Dakota, and central Missouri. Shafer (2011) presented information on typical yield losses for many of the states in the Corn Belt region of the United States. In Minnesota, yield losses declined from 97 percent of yield potential on May 5th to 59 percent of yield potential by June 19th.

Ransom (2014a) indicated that yield for corn in southeastern North Dakota declines about 1.1 to 3 bushels per day by June 1st. Those rates, based on estimated yield potential (see Tables 9 and 10 for target yields), would equate to about 0.75 percent to 2.2 percent per day. Ransom (2014b) indicated a general rule of thumb would be 1 percent per day yield loss past optimal planting window. Lauer (2015) provided information on yield effects of planting delays for several growing regions in Wisconsin. The northern growing region of Wisconsin is considered a 70-95 day maturity zone for corn. Yield losses in that maturity zone were expected to be 36 percent to 38 percent when planting was delayed to June 1st.

Producers who participated in the focus group session indicated yield losses ranging from 2 percent to 5 percent per day (NDSU Focus Group 2014). However, producers indicated 5 percent per day was considered an absolute maximum loss. The majority of producers felt losses around 2 percent per day were more common. However, a 2 percent per day yield loss would result in a 60 percent decline in yield by June 1st. The degree of yield loss using a linear rate of 2 percent per day exceeded published estimates, and was inconsistent with producers' decision to switch from corn to soybeans around June 1st. Expected yields using a 2 percent per day yield loss would suggest producers would continue to plant when expected yields dropped below 60 bushels per acre in the staging area, which would coincide with switching corn to soybeans around June 1st. Producers would likely switch corn to another crop prior to reaching the point where yield potential for corn was 60 bushels per acre or less. The northern growing region of Wisconsin was perceived to be a reasonable proxy for the growing region in the southern Red River Valley. The yield loss reported for planting delays for northern Wisconsin resulted in yield declines that were between 1 percent and 2 percent yield loss per day by June 1st (Figure 24).

The University of Minnesota yield losses for corn were considered to be heavily influenced by a longer growing season as much of the state's corn is produced further south than the FM Diversion staging area. The longer growing season decreases the risk of early frost, and usually increases the potential for a warmer growing season, which can mitigate the yield declines associated with delay planting. The 2 percent per day linear rate was perceived to overestimate the yield declines for corn in the study region. The yield loss from northern Wisconsin was considered the best fit for this study.

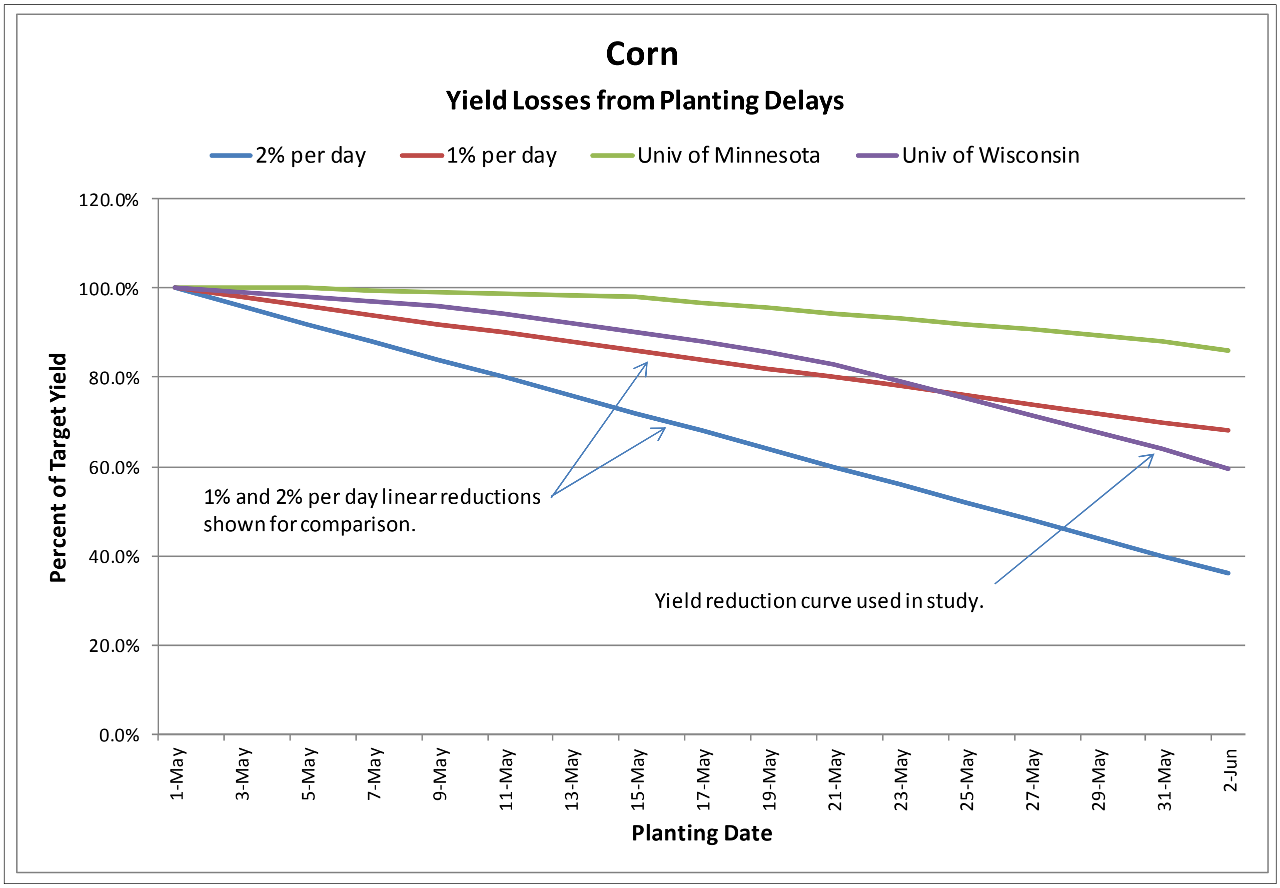

Figure 24. Yield Responses to Delayed Planting for Corn.
Sources: Lauer (2015); Coulter (2015); NDSU Focus Group (2015).

-) Wheat

Ransom (2014a) reported yield losses for wheat to be around 1.5 bushels per day for planting after optimal dates. Ransom (2014b) indicated a general rule of thumb would be a 1 percent per day reduction in wheat yield for acreage planted after the optimal date. Producers who participated in the Focus Group session indicated yield losses were around 1 bushel per day for delayed planting. Based on target yields, a yield loss of 1 bushel per day represented 1.6 percent per day. A yield loss of 1.5 bushels per day would represent a yield loss of 2.4 percent per day. This study used a 1 bushel per day yield loss associated with delayed planting, which equates to about 1.6 percent per day (Table 19).

Table 19. Yield Rate Declines Associated With Planting Delays, Red River Valley		
	Last Optimal Calendar Date for Planting	Relative Yield loss if Planting Occurs after Optimal Date
Wheat[a]	April 30	1.67% per day
Corn[b]	May 1	Week 1-3.5%, Week 2-9.9%, Week 3-19%, Week 4-32.1%
Soybeans[c]	May 20	0.5% per day
Sugarbeets[d]	May 1	1.0% per day

[a] Ransom (2014a, 2014b); NDSU Focus Group (2015).
[b] Ransom (2014a, 2014b); Lauer (2015).
[c] Ransom (2014b), optimal dates. Severson (2014) and Kandel (2015), yield losses.
[d] Metzer (2015); Peters (2015).

Value of Switch Acres

Wheat acreage switched to soybeans was valued at the per-acre gross revenue for wheat using wheat yield on the date when the acreage was switched. Soybeans are a relatively higher value crop than wheat and switching acres of wheat to soybeans might skew the estimated revenues associated with planting delays. To avoid generating a revenue premium for switching wheat acreage to soybeans, the acreage of wheat switched to soybeans was not valued based on subsequent soybean production from those acres, but rather was estimated by multiplying the expected wheat yield as of June 1 by the price for wheat. This valuation process was applied to all wheat acres switched to soybeans. Corn acreage switched to soybeans was estimated using the same methods as wheat.

Soybeans were modeled to not have a switch crop. If soybean acreage was not completed by the prevent plant deadline, all remaining acres of soybeans were considered idle for the season.

Sugarbeets also were modeled to not have a switch crop. Although the prevent plant date for sugarbeets is May 31, few acres of sugarbeets are ever claimed as prevent plant in the study counties (Appendix D). Typically, sugarbeets are planted until all acres are completed, even if planting extends beyond May 31. Prevent plant acreage for sugarbeets was not included in the analysis.

Event-level Losses to Annualized Values

To produce an annualized expected revenue loss associated with the use of the staging area, a probability density function (PDF) was produced from the event-level values. The PDF represents a combination of the probabilities of occurrence and expected damages (Figure 25). It would, by default, also include zero losses for the annual probably that no flood event occurred. A mathematical technique that computes the integral of the PDF is then used to estimate annualized values.

The five flood events represent a given set of discrete points and flood frequencies; it is necessary to fit a piece-wise linear function through the points to approximate the underlying probability density function. In Figure 25, the points of the individual flood events are represented by a label.

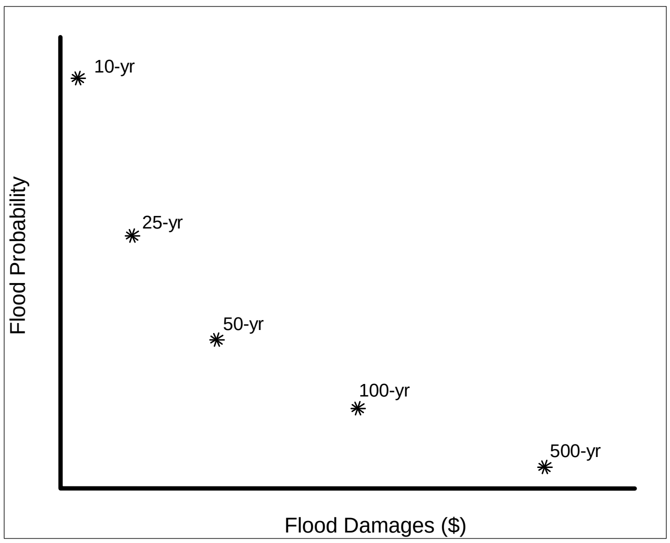

Figure 25. Conceptual Representation of Flood Event-Level Damages and Probabilities.

In Figure 26, linear segments connect each of the points (flood events). An integral is used to compute expected damages as follows

$$\exp(losses) = \int_{n=1}^{N} prob_n * loss_n$$

where n = five flood scenarios (10-, 25-, 50-, 100- and 500-year events)

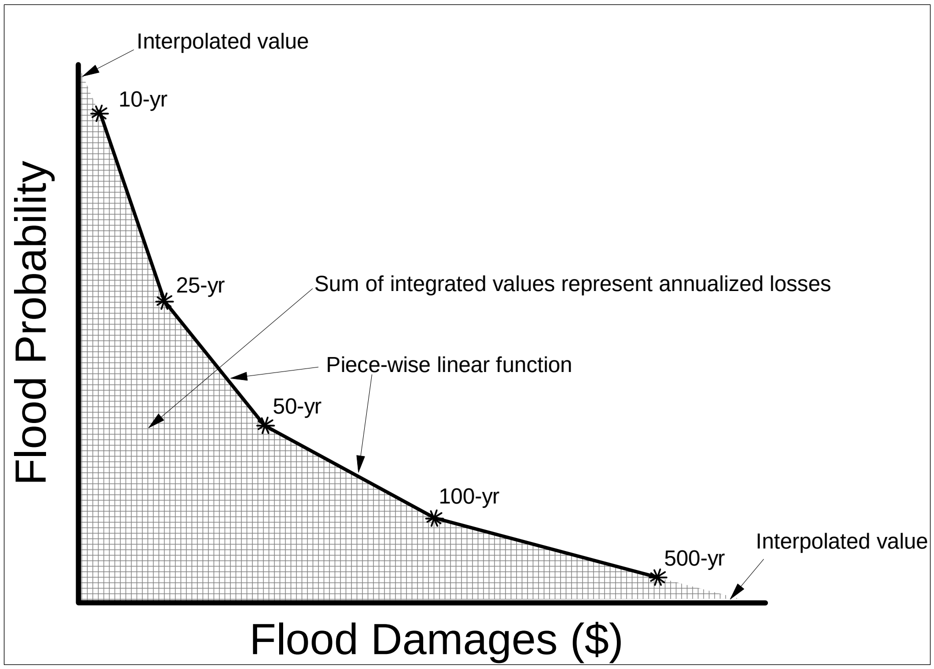

Figure 26. Conceptual Diagram of Flood Frequency and Flood Damages within a Piece-wise Linear Function.

Study Limitations

This study is not without limitations. Some of those limitations and assumptions are related to available data while other shortcomings are based on limitations of the methodology. Further, some limitations are a natural consequence of limited resources and definitive timelines that prevent studying every caveat of an issue.

Combining weather and producer behavior is difficult, and the study was not able to include all factors that may affect spring planting, yield loss, or reductions in producer incomes in the staging area. The following topics are acknowledgements of the additional issues or refinements that could be included in future studies. Further, this list helps to reiterate the complexities of modeling all of the potential producer effects that may result from the FM Diversion. By identifying and discussing these issues, stakeholders, planners, producers, landowners, and the general public will have a clear understanding of the study.

If all of the potential subjects or issues could be adequately incorporated into future studies, they would refine the magnitude of losses and further articulate producer-level effects. However, aside from perhaps the largest omission (e.g., farm insurance), the study's current data and methodology could potentially draw similar conclusions even if the omitted factors were addressed. This is due to the general relationship between when the staging area would be activated and when producers are expected to be able to begin planting. Unless the hydrology effects were to substantially change, those fundamental relationships would remain present in an expanded study.

- **Crop Insurance**: The study did not take federal crop insurance into consideration. Crop insurance is an important financial tool for producers. Several important questions would need to be addressed with respect to crop insurance including eligibility if the staging area is used and potential affects in non-flood years from adjustments to lower yields in a flood year.

- **Land Productivity**: The study does not address short- and long-term land productivity issues, how water storage may affect soil organisms, soil compaction, erosion or other soil/agronomy concerns

- **Flood Debris**: Debris is a big concern for producers, especially for the storage areas that do not currently flood. Flooding creates a shoreline effect, or depositing of crop residue and other materials at the edge of flood waters. These deposits of debris can be problematic depending upon water inundation, previous year's crop, fall tillage, field topography, or deposits of non-agricultural materials (e.g., trees, garbage). Debris left by flood waters increases the dry-down time in areas of deposits and increases time requirements to prepare a field for planting. Producers indicated that no single method exists to easily manage flood debris. Some of the more common methods include burning, moving the debris to field edges, or using tillage to disperse the debris. Land under the debris windrows or deposits will not dry-down at the same rate as non-covered areas. The study assumed that debris was handled within the 10-day dry-down period.

- **Use of State-level Data**: State-level data for sugarbeet planting in North Dakota was used for planting start dates for wheat, corn, and sugarbeets. Planting conditions throughout the spring can vary substantially at a state level. This is especially so if a crop is raised over a large area (e.g., wheat in North Dakota, corn in Minnesota). The study did not have historical data on planting start times specific to the staging area.

  Also, different statistical approaches to creating planting start times should be more fully investigated in future analyses. Current techniques and assumptions on the independence of planting data produced some unlikely combinations in the simulation. Ideally, planting progress data with geographic specificity to the study area would provide the most consistent statistical distributions. Adjusting the distributions of planting start dates to be conditional or jointed to more than one factor could represent an improvement over techniques used in this study.

- **Likelihood of Prevent Planting in Non-flood Years**: The analysis does not include the potential adjustment to the likelihood of prevented planting occurring the year after a prevented plant season. Effects of temporary water storage were limited to a single planting season.

- **Dry-down Period**: The 10-day dry-down period is an assumption based on professional opinion of producers and soil scientists. Empirical data on actual dry-down times following flood inundation were not available. Dry-down is a function of precipitation (fall and spring), temperature in the spring, presence or absence of fall tillage, soil type, wind, cloud cover, and crop residue. The month of May tends to receive more precipitation than the month of April. The implication is that if water recedes from a flood event in April, the relative dry-down period may be shorter than if water recedes from a flood event in May.

  Since inundated lands are saturated after water leaves the land, their ability to absorb additional moisture is likely to be considerably less than non-flooded lands. The study does not estimate the probability of a rain or precipitation event occurring during the dry-down period. The dry-down period can potentially vary by storage area, so the exact calendar dates for dry-down periods will not necessarily be the same among all inundated storage areas.

- **Economics of Crop Switching**: The study did not include the influences that relative profitability of particular crops might play on a producer's decision to switch planting to other crops. For example if corn price is high and profitability from corn is perceived or anticipated to better than soybeans (even with reduced yields), producers may plant beyond the date when they would normally switch corn acreage to soybean acreage. The opposite may occur if corn profitability is perceived to be lower than soybeans—producers may switch late planted corn acreage to soybeans earlier in the planting season than otherwise suggested.

- **Alternative Maturity Varieties:** Switching the maturity of certain crop varieties, primarily corn and soybeans, may be a potential strategy for producers to mitigate planting delays. However, shorter maturing crops generally yield less than longer maturing crops, and the net difference in a delayed planting start with a shorter maturity variety versus a longer maturing variety is not clear. Also related to the issue of switching maturities for crops would be the economics of crop switching, which could include an added element of alternative maturing crop varieties.

- **Crop Mix Within Storage Areas**: The study had to assume an equal distribution (percentage) of the region's crops among each storage area. In reality, many storage areas may only produce one or two crops in any given season.

- **Yield Potential versus Actual Yields**: The yields used in the model were based on a combination of NASS data and information from producers. It was beyond the scope of this study to determine to what degree historical spring planting conditions have influenced yields. Alternatively, a number of factors affect yield, and those factors are present throughout most of the growing season. Planting conditions are one of many factors that affect yield in any given year. It may be more accurate to estimate a yield potential based on conditions remaining favorable throughout the season. A yield estimate based on those factors would perhaps more closely match the potential yield reductions associated with delayed planting.

- **Crop Quality**: The study did not incorporate any crop quality issues. For example, the potential effect of delayed planting on sugar content for sugarbeets was not addressed in the study.

- **Organic Crop Production**: It is unclear what effects temporary water storage may have on organic producers within the storage area. Those effects may include a loss of certification due to the presence of flood waters and/or a difference in revenue loss from delayed planting if organic yields and prices are different from those used in this study.

- **Sub-surface Drain Tile**: The presence or absence of subsurface drain tile was not included in the hydrology modeling, nor considered in the assumptions for dry-down time used in the analysis. NDSU Extension agronomists indicate that drain tile, in many circumstances, can facilitate faster removal of spring flood waters and reduce dry-down time after a flood event. Data on the acreage currently using subsurface drain tile within the staging area were not collected, and current hydrology modeling by the FM Diversion Authority has not incorporated the potential improvement in rate of flood water drainage due to subsurface drain tile. While subsurface drain tile may improve dry-down time, data were not available to quantify that improvement. Considering the expense of installing drain tile, it would be unlikely that reducing planting delays associated only with flood years would be economically sufficient to justify the expense of installing drain tile.

- **Production Costs and Profitability**: While the study focused on producer revenues, another important element pertains to profitability. The analysis did not address any potential changes in production costs that could arise from the presence of the Diversion, nor does the analysis provide estimates of the lost *Net Revenue* for producers.

Results

This study examined several important issues related to how temporary water storage in the FM Diversion staging area might affect spring planting. Below is an outline of study findings.

<u>Evaluation of Potential Planting Delays:</u> This section examines the length of time needed for the effects of flooding to be gone and matches that information with planting progress data to estimate the probability of incurring planting delays.

<u>Converting Planting Delays into Revenue Losses:</u> This section demonstrates how the model combines planting periods and planting start dates for all four crops for both With and Without Diversion conditions to estimate revenue losses. An example is provided using data from Monte Carlo simulation.

<u>Evaluation of 10-year, 25-year, 50-year, 100-year, and 500-year Flood Events:</u> Estimates of the frequency of revenue losses are presented by hydrology group and size of flood event. Gross revenues per acre are provided by hydrology group for flood years with existing conditions and conditions With the Diversion. The gross revenues represent a combined average of all four crops with all storages areas within the hydrology groups across the entire range of conditions generated in the Monte Carlo simulation.

> <u>Estimation of Gross Revenues Only in Years With Losses:</u> Gross revenues are presented for only conditions that produce a revenue loss. Conditions when planting delays were not observed were removed to provide a more accurate estimate of the value of the revenue loss if there was a planting delay.
>
> <u>Estimation of Potential Revenue Losses by Crop</u>: The difference in per-acre revenues between existing conditions and With the Diversion are provided by crop and size of flood event. The estimates would be analogous to the per acre revenue losses if only a single crop comprised the entire acreage with a storage area.
>
> <u>Distribution of Total Revenue Losses</u>: Total revenue losses are presented graphically to view the magnitude of potential liabilities in the staging area.

Evaluation of Potential Planting Delays

Two key factors in assessing the likelihood of planting delays included 1) how much time flooded lands require for the effects of flooding to be gone and 2) how long after a flood event until general planting begins. Data on flood start dates (i.e., when the Diversion staging area would be activated), historical data on regional planting progress, and hydrology data on the duration of flooding Within the Diversion staging area were evaluated and used in the Monte Carlo simulations.

The follow section examines the number of days from when the staging area is activated to when the effects of flooding would be gone and compares that to the number of days from flood start (i.e., staging area activation) to when regional planting begins. Flooding results in delayed planting when inundated lands require for the effects of flooding to be gone than the time from flood start to when regional planting begins. Stated alternatively, if regional planting begins before the effects of flooding are over for inundated lands, those lands will experience delayed planting. However, the analysis focuses on 1) the additional time the Diversion adds to when the effects of flooding are gone, and 2) how often those additional days result in planting delays.

Flood Dates and Planting Dates for Wheat, Corn, and Sugarbeets

Key factors in the study include when the Diversion staging area would be activated and when planting begins in the region. Knowing the date when the staging area is activated is critical because that starts the countdown to when the effects of flooding will be gone. Likewise, when producers are able to begin planting, based on general spring conditions, is critical since that provides a date that can be used to estimate potential planting delays.

Historical dates when the Red River first reached 17,000 cfs was compared to historical dates when planting began for North Dakota sugarbeets (Figure 27). The reason for examining the date when the Red River reaches 17,000 cfs is because that date corresponds to when the staging area would be activated[11]. Dates when the Red River has reached 17,000 cfs in Fargo have ranged from March 19, 2010 to April 12th, 2001. The average date the flood events reached 17,000 cfs was March 31st. The hydrology modeling provided by the FM Diversion Authority uses the Diversion activation date as the time from which the water flow is evaluated, and the Diversion activation date for this study is when the Red River reaches 17,000 cfs in Fargo.

The number of days from when the Red River in Fargo reached 17,000 cfs to the start of spring planting ranged from 9 days in 2001 to 25 days in 2009 (Figure 27). The average number of days between the Red River reaching 17,000 cfs and the start of spring planting (i.e., first date reported) was 18 days. If the 20 percent of planting completion threshold is used, the average number of days increases to 29 days. This study used a 20 percent threshold to estimate when most producers are actively planting. The historical data suggest a range from 19 to 38 days from when the Red River in Fargo reaches 17,000 cfs until spring planting reaches 20 percent completion. The average is 29 days (Table 20).

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[11] Operation of the staging area is expected to use gauge information upstream of Fargo; however, those details will be finalized when the operational plan for the staging area is completed. This study used Fargo gauge dates as a point in time when the staging area would be activated.

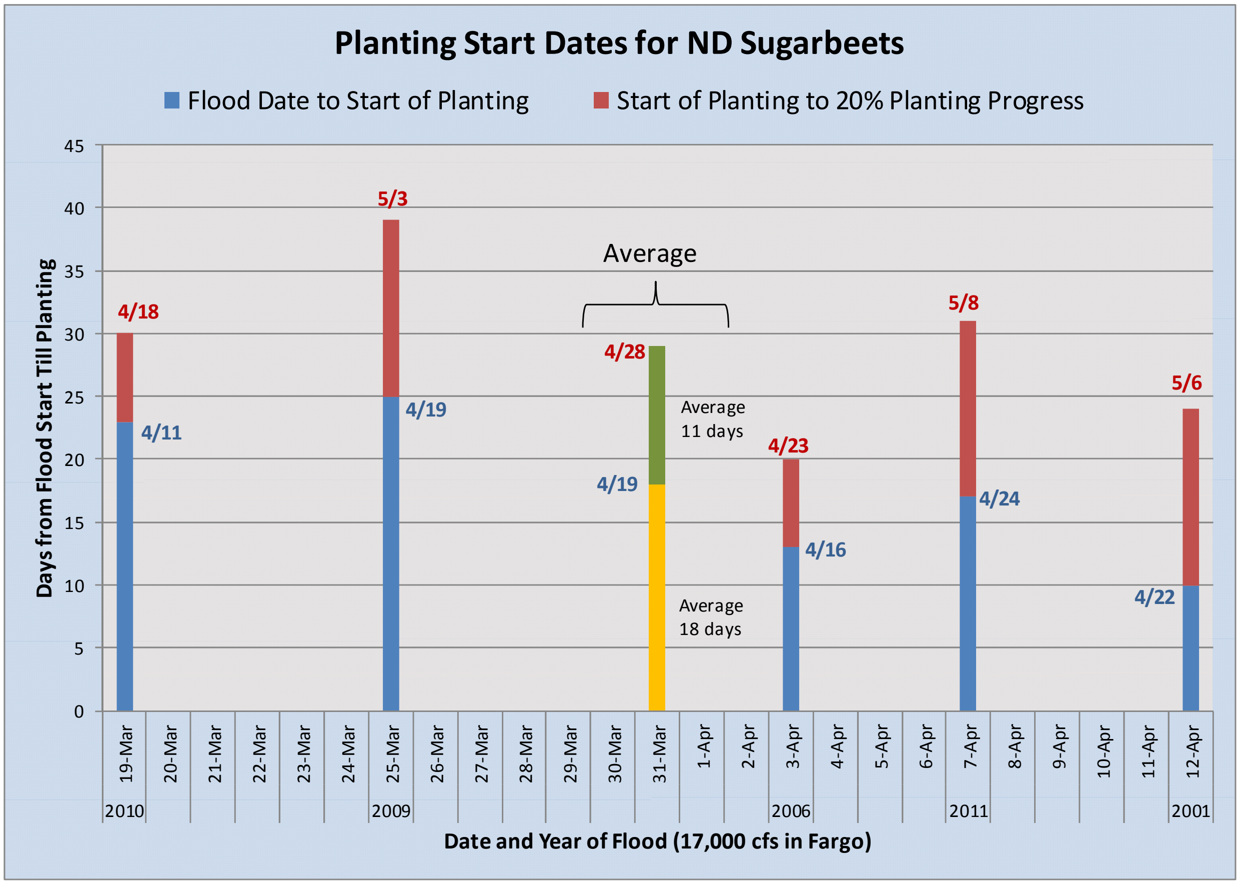

Figure 27. Historical Planting Start Dates for North Dakota Sugarbeets and Dates when Red River Reached 17,000 cfs in Fargo, 2000 through 2014.
Source: National Agricultural Statistics Service (2015); U.S. Geological Survey (2105).

Figure 27 and Table 20 identify the difference in regional planting start dates and the dates when the Red River reached 17,000 cfs in Fargo. Another element of the planting data is to compare planting start dates for years *without* major flood events to the planting start dates *with* major flood events. The data indicate that a major flood event does not always lead to a later spring planting start date (Figure 28). In recent years (e.g., 2013 & 2014), spring planting start dates have been later than the planting start dates in flood years 2006, 2009, and 2010. If a 20 percent threshold is used to evaluate planting start dates, the start date in 2014 exceeds the same metric in all years with a major flood event (Figure 29). Also in 5 of the last 15 years, regional planting dates to reach 20 percent completion in non-flood years are later than the planting dates in two of the five flood years. The historical data suggest that a major flood event is not always going to result in regional planting dates being later than dates for non-flood years (Figure 29).

Table 20. Historical Dates, Red River Reaches 17,000 cfs in Fargo, Regional Planting Start Dates for Sugarbeets in North Dakota, 2000 through 2014					
Major Flood Events[a]		Regional Planting Start Date[a]			
Year	Date when Red River Reaches 17,000 cfs in Fargo	0 Percent Completion	20 Percent Completion	Days Between Flood Start and Start of Spring Planting	Days Between Flood Start and 20% Completion of Spring Planting
2010	March 19	April 11	April 18	23	29
2009	March 25	April 19	May 3	25	38
2006	April 3	April 16	April 23	13	19
2011	April 7	April 24	May 8	17	30
2001	April12	April 22	May 6	10	23
Average	March 31	April 18	April 29	18	29

[a]Planting progress data for flood years 1997, 1989, 1979, and 1969 were not available.
[b]Data for North Dakota sugarbeet planting progress.
Source: National Agricultural Statistics Service (2015); U.S. Geological Survey (2015).

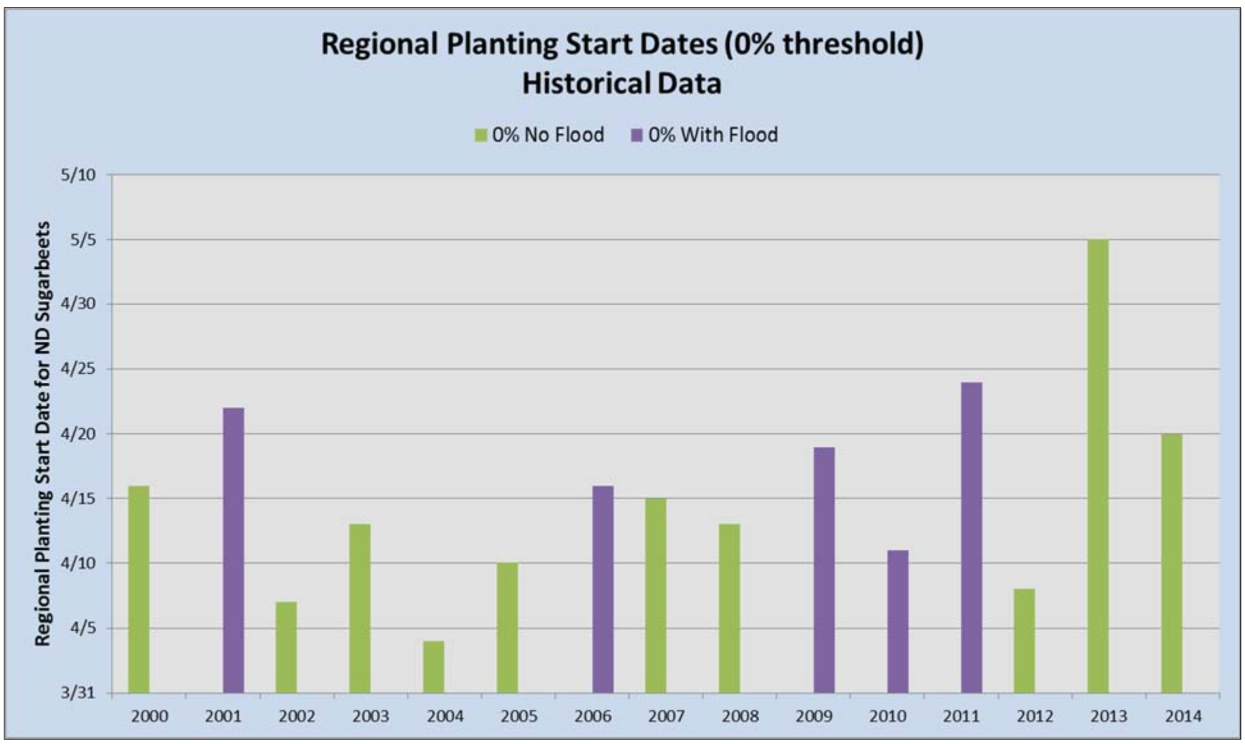

Figure 28. Comparison of Planting Start Dates for North Dakota Sugarbeets in Flood and Non-flood Years, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

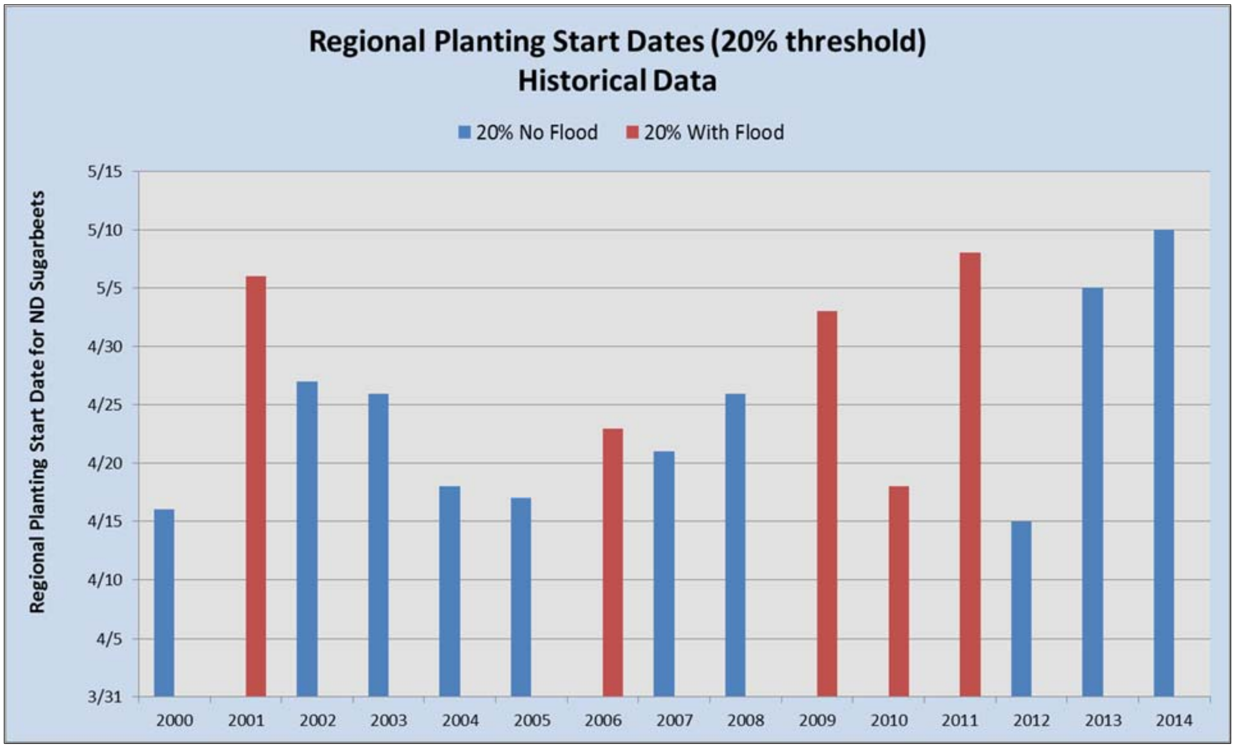

Figure 29. Comparison of Dates for 20 Percent Planting Completion for North Dakota Sugarbeets in Flood and Non-flood years, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

Historical data on when the Red River has reached 17,000 cfs were used to produce a distribution of dates that are likely given the ability of the historical data to predict future flood dates. [The range of flood dates used in the simulation also is discussed in the Methodology section, see Figure 13]. A statistical analysis of the data provided both a range of calendar dates and the future likelihood (i.e., probability) of the staging area being triggered on those dates. While the distribution developed for this study limits flood event start dates from March 19 to April 18 (Figure 30), the distribution should not be interpreted as suggesting there is zero probability of a flood event start date falling outside of that range. While the likelihood may be extremely low, that possibility still exists.

Historical data on when regional planting has reached 20 percent completion were used to produce a range and future probability for those dates. However unlike the flood start dates, the historical planting completion data suggested that a nearly equal chance exists in any given year that planting of sugarbeets in North Dakota will fall between April 14 and May 10. [The range of spring planting start dates used in the simulation is discussed in the Methodology section, see Figures 14 and 15]. The sugarbeet data also were used as a proxy for the planting start dates for wheat and corn.

Combining the distribution of dates for regional planting and dates for activation of the staging area can illustrate the number of days between the triggering of the staging area (17,000 cfs in Fargo) to when regional planting completion has reached 20 percent (Figure 31). Statistics used to produce the distributions indicate that those dates actually overlap in a small number of potential combinations; however, the analysis eliminated any situations where a regional planting date precedes a flood start date.

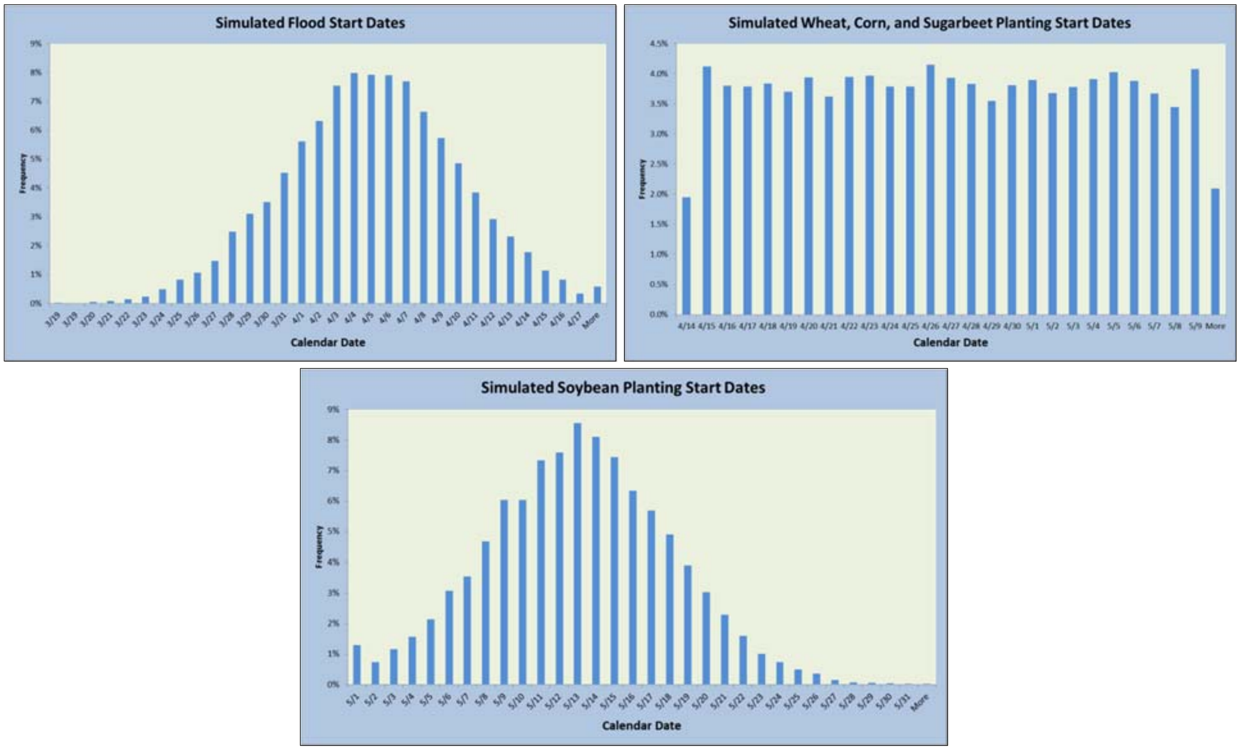

Figure 30. Distributions of the Dates for Staging Area Activation, Corn, Wheat, Sugarbeets, and Soybean Planting Dates Corresponding With 20 Percent Completion.

The statistical distributions not only can show the range of days between staging activation date and regional planting dates, but also can illustrate the frequency or probability of that range. Figure 28 and Table 20 already illustrate that the historical data show a range of 10 to 25 days from when the Red River reaches 17,000 cfs in Fargo and when planting activity is first reported by NASS. Also, the historical data show a range of 19 to 38 days from when the staging area would be triggered to when planting progress reaches 20 percent completion. Over the 10,000 replications, the difference (in days) between staging area activation and when regional planting reaches 20 percent completion varied from 0 days to 49 days (Figure 31). While the simulation produced a range larger than observed with existing data, the chance of the difference exceeding 40 days or being less than 10 days is about 12 percent (Table 21). About 70 percent of the replications in the simulation suggest that the difference between the staging area activation date and when regional planting may reach 20 percent completion falls between 11 and 30 days. Alternatively, the difference between the staging area activation date and regional planting date will be 11 to 30 days over 70 percent of the time (Table 21).

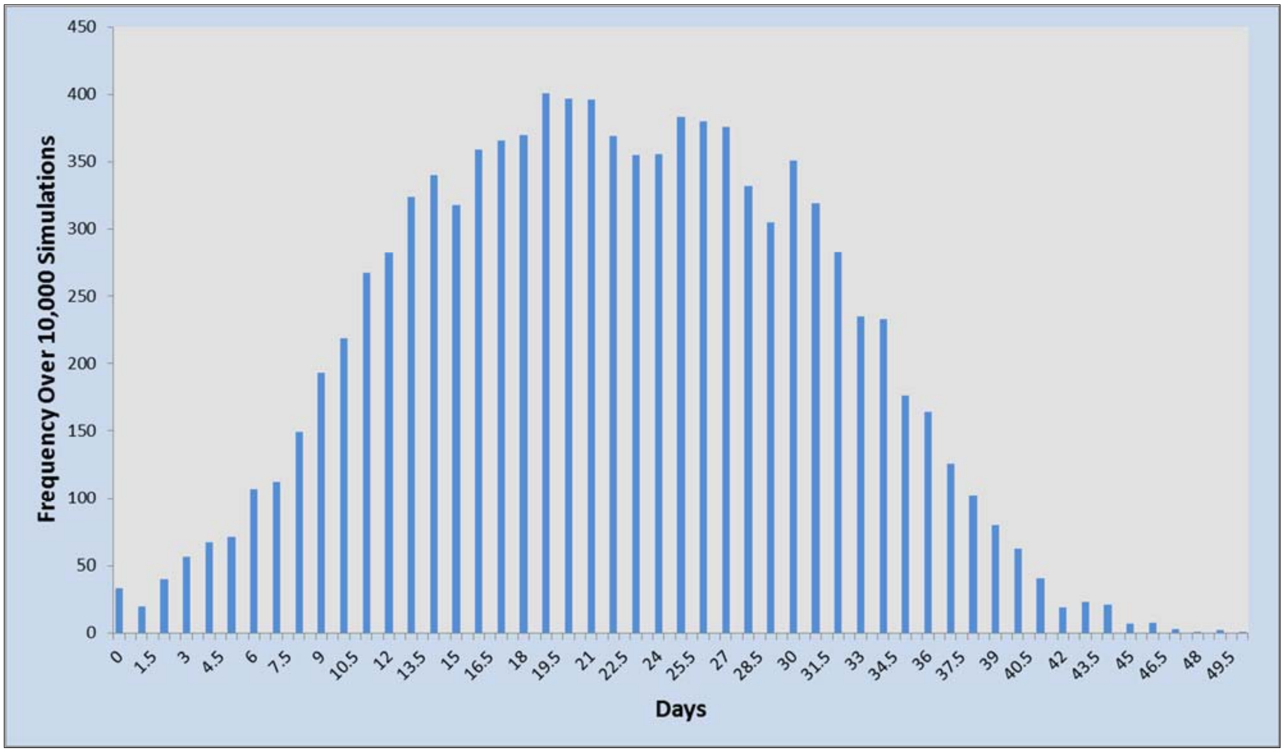

Figure 31. Monte Carlo Simulation, Difference in Days between Staging Area Activation and Regional Planting Reaching 20 percent Completion, Sugarbeets, Corn, and Wheat.

Table21. Monte Carlo Simulation, Distribution of the Difference in Days between Staging Area Activation and Regional Planting Reaching 20 percent Completion for Sugarbeets, Corn, and Wheat

Days[a]	Number of Replications	Percent of Monte Carlo Simulation
0	21	0.2
1 to 15	2,259	22.6
16 to 20	1,814	18.1
21 to 25	1,873	18.7
26 to 30	2,127	21.3
31 to 35	1,070	10.7
36 to 40	648	6.5
41 to 45	166	1.7
>45	22	0.2

[a] Days were estimated by subtracting the flood start date (date when staging area is activated) from the regional planting start date (20% threshold). Days therefore represent the time required for the effects of flooding to be gone without incurring a planting delay due to a spring flood event.

Flood Start Dates and Planting Dates for Soybeans

Historical dates when the Red River first reached 17,000 cfs were compared to historical dates when planting began for North Dakota soybeans (Figure 32). The reason for examining the date when the Red River reaches 17,000 cfs is because that date corresponds to when the staging area would be activated.

The number of days from when the Red River in Fargo reached 17,000 cfs to the start of spring planting of soybeans ranged from 24 days in 2001 to 54 days in 2009 (Figure 32). The average number of days between the Red River reaching 17,000 cfs and the start of spring planting for soybeans was 35 days. If the number of days required to reach 20 percent of planting completion is included, the average number of days increases to 45 days. This study used a 20 percent threshold to estimate when most producers are actively planting. The historical data suggest a range from 31 to 58 days from when the Red River in Fargo reaches 17,000 cfs until spring planting for soybeans reaches 20 percent completion. The average is 45 days (Table 22).

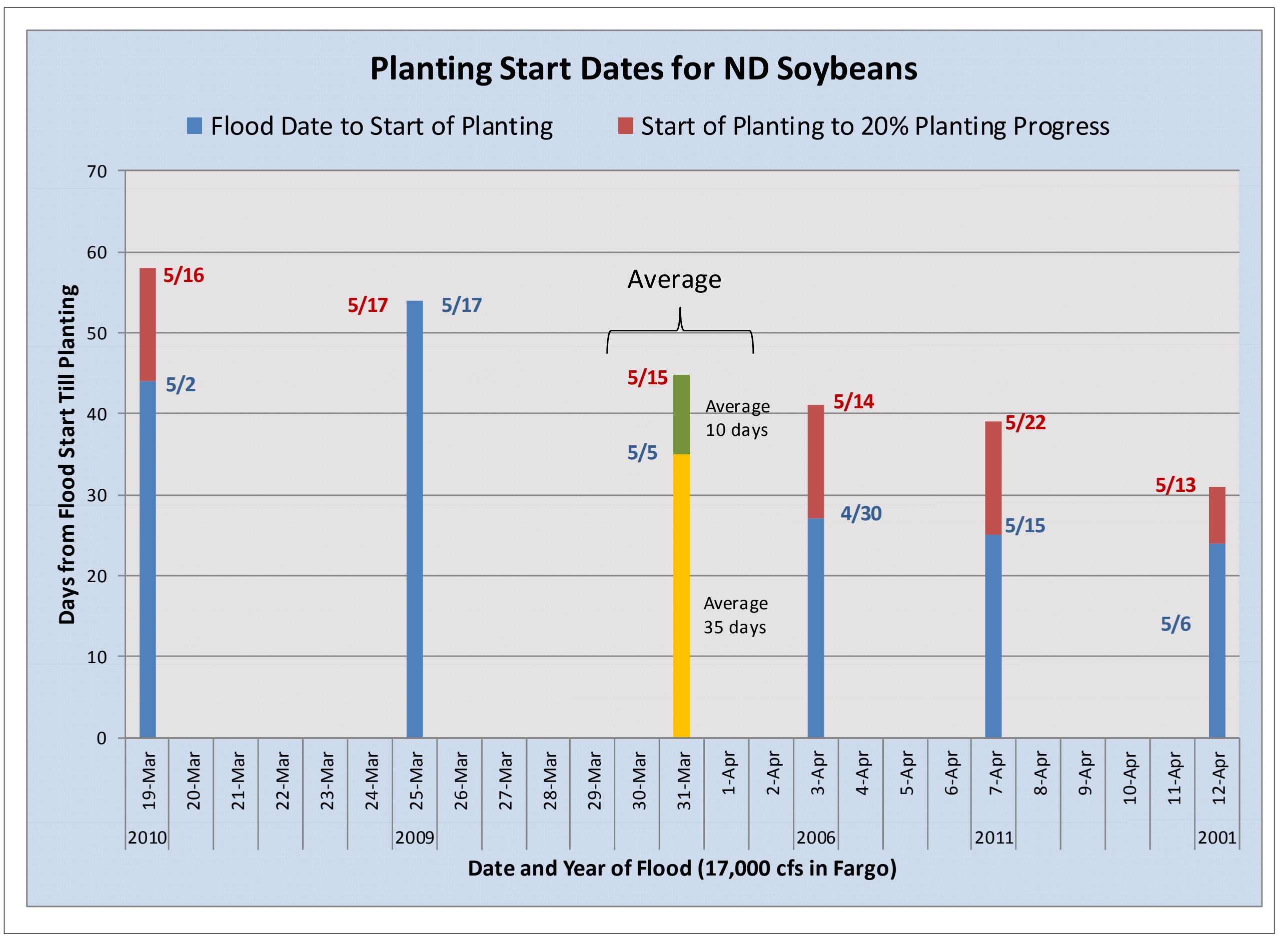

Figure 32. Historical Planting Start Dates for North Dakota Soybeans and Dates when Red River Reached 17,000 cfs in Fargo, 2000 through 2014.
Source: National Agricultural Statistics Service (2015); U.S. Geological Survey (2105).

Figure 32 and Table 22 identify the difference in regional planting start dates for soybeans and the dates when the Red River reached 17,000 cfs in Fargo. Another element of the planting data is to compare planting start dates for years *without* major flood events to the planting start dates *with* major flood events. The data indicate that a major flood event does not always lead to a later spring planting start date for soybeans (Figure 33). Aside from flood years 2009 and 2011, spring planting start dates between flood years and non-flood years are similar. If a 20 percent threshold is used to evaluate planting start dates, the start date in 2003 exceeds the same metric in all years with a major flood event (Figure 34). Also in 10 of the last 15 years, regional planting dates for four flood years and six non-flood years have started approximately in the same week. The historical data suggest that a major flood event is not always going to result in regional planting dates for soybeans being later than dates for non-flood years (Figure 34).

Table 22. Historical Dates, Red River Reaches 17,000 cfs in Fargo, Regional Planting Start Dates for Soybeans in North Dakota, 2000 through 2014

Major Flood Events[a]		Regional Planting Start Date[a]			
Year	Date when Red River Reached 17,000 cfs in Fargo	0 Percent Completion	20 Percent Completion	Days Between Flood Reaching 17,000 cfs in Fargo and Start of Spring Planting	Days Between Flood Reaching 17,000 cfs in Fargo and 20% Completion of Spring Planting
2010	March 19	May 2	May 16	44	58
2009	March 25	May 18	May 17	54	54
2006	April 3	April 30	May 14	27	41
2011	April 7	May 15	May 22	25	39
2001	April12	May 6	May 13	24	31
Average	March 31	May 5	May 15	35	45

[a]Planting progress data for flood years 1997, 1989, 1979, and 1969 for North Dakota for corn, soybeans, and sugarbeets were not available. Spring wheat, barley and oats planting progress data were available for 1997, but not available for 1989, 1979, and 1969.

[b]Data for North Dakota Sugarbeet planting progress.

Source: National Agricultural Statistics Service (2015); U.S. Geological Survey (2015).

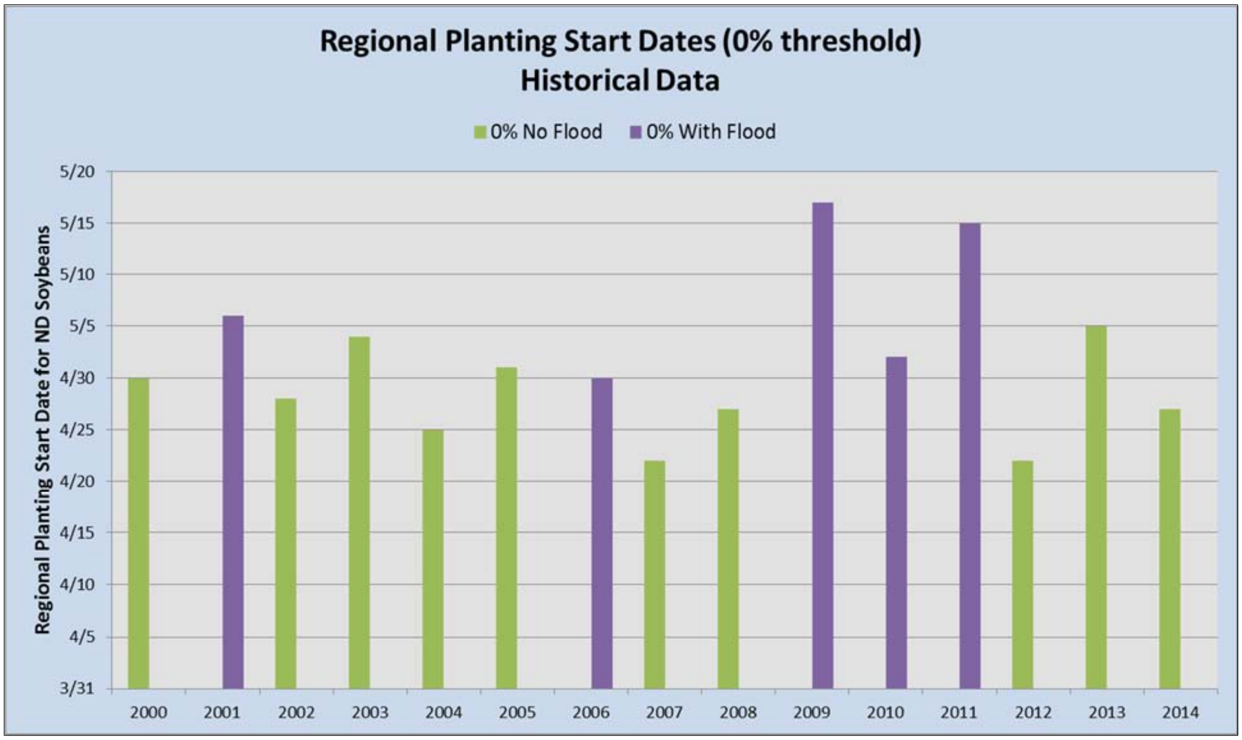

Figure 33. Comparison of Planting Start Dates for North Dakota Soybeans in Flood and Non-flood Years, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

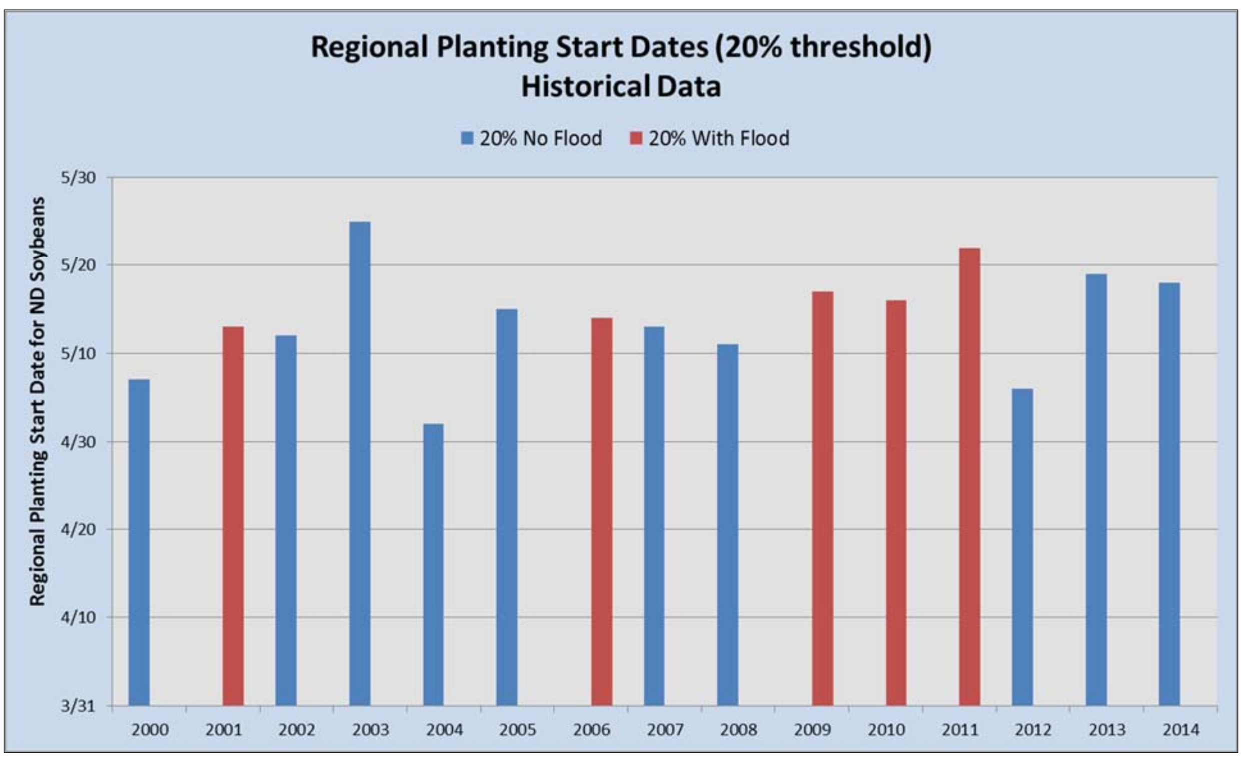

Figure 34. Comparison of Dates for 20 Percent Planting Completion for North Dakota Soybeans in Flood and Non-flood Years, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

Historical data on when regional planting for soybeans has reached 20 percent completion were used to produce a range and future probability for those dates. The historical planting completion data suggested that planting of soybeans in North Dakota will fall between May 1 and May 31, with an average start date around May 13. [The range of spring planting start dates used in the simulation for soybeans is discussed in the Methodology section, see Figure 15].

Combining the distribution of dates for regional planting and dates for activation of the staging area can illustrate the number of days between the triggering of the staging area (17,000 cfs in Fargo) to when regional planting completion for soybeans has reached 20 percent (Figure 35).

The statistical distributions not only can show the range of days between staging activation date and regional planting dates, but also can illustrate the frequency or probability of that range. Figure 32 and Table 22 already illustrate that the historical data show a range of 24 to 54 days from when the Red River reaches 17,000 cfs in Fargo and when planting activity for soybeans is first reported by NASS. Also, the historical data show a range of 31 to 58 days from when the staging area would be triggered to when planting progress reaches 20 percent completion. Over the 10,000 replications, the difference (in days) between staging area activation and when regional planting reaches 20 percent completion varied from 10 days to 61 days (Figure 35). While the simulation produced a range larger than observed with existing data, the chance of the difference exceeding 50 days or being less than 15 days is about 4 percent (Table 23). About 80 percent of the replications in the simulation suggest that the difference between the staging area activation date and when regional planting may reach 20 percent completion falls between 30 and 50 days. Alternatively, the difference between the staging area activation date and regional planting date will be 30 to 50 days over 80 percent of the time (Table 23).

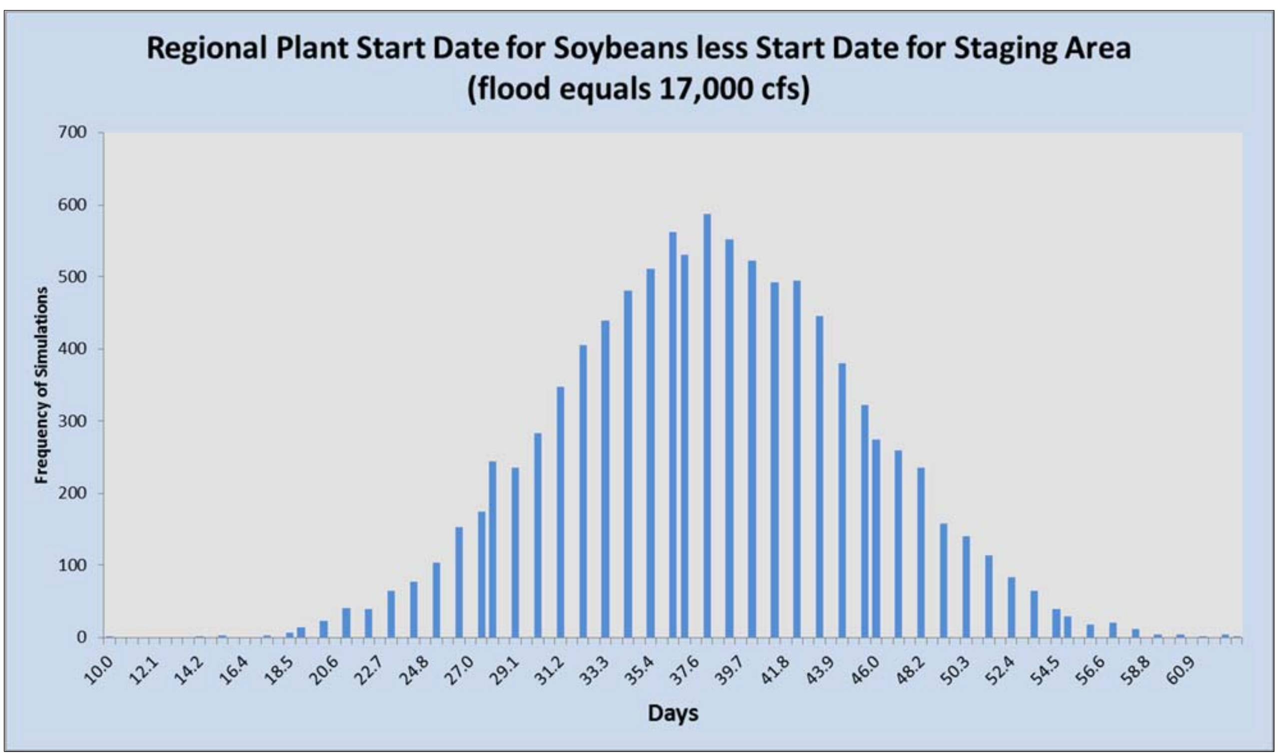

Figure 35. Monte Carlo Simulation, Difference in Days between Staging Area Activation and Regional Planting Reaching 20 percent Completion for Soybeans.

Table 23. Monte Carlo Simulation, Distribution of the Difference in Days between Staging Area Activation and Regional Planting Reaching 20 percent Completion for Soybeans		
Days[a]	Number of Replications	Percent of Monte Carlo Simulation
0-15	3	0.0
16-20	27	0.3
21-25	246	2.5
26-30	1,193	11.9
31-35	1,672	16.7
36-40	3,265	32.7
41-45	1,811	18.1
46-50	1,388	13.9
>50	395	4.0

[a] Days were estimated by subtracting the flood start date (date when staging area is activated) from the regional planting start date (20% threshold). Days therefore represent the time required for the effects of flooding to be gone without incurring a planting delay due to a spring flood event.

Time Required for Effects of Planting to be gone During Flood Years

A critical element in evaluating the potential agricultural implications of short-term water storage on farmlands in the FM Diversion staging area relates to the duration or absence of water storage within the staging area. Understanding the differences in water storage between the Without Diversion and With Diversion conditions forms the basis to evaluating the potential effects on spring field work.

In all flood event sizes except the 10-year event, the majority of acres in the staging area have 16 to 25 days from activation of staging area until the effects of flooding are gone (Table 24). Acreage associated with more than 25 days until the effects of flooding are over is relatively small in the 25-year and 50-year events, but increases in the 100-year and 500-year events. For example, the number of acres that would require 25 or more days for the effects of flooding to be over ranges from around 2,500 acres in the 25-year event to 17,900 acres in the 500-year event. As would be expected, as the size of the flood event increases, more acres require a longer period for the effects of flooding to be gone (Table 24).

Table 24. Total Days from Staging Area Activation until the Effects of Flooding are gone, With and Without Diversion, by Size of Flood Event

	Size of Flood Event									
Total	10-year		25-year		50-year		100-year		500-year	
Days[a]	W	WO	W	WO	W	WO	W	WO	W	WO
	---- acres of storage areas ----									
0	31,784	32,397	13,900	25,378	8,991	22,485	3,918	18,405	1,382	11,413
1-15	726	726	726	2,096	638	292	0	1,084	0	0
16-20	10,967	10,354	8,962	9,580	11,461	11,723	9,539	10,661	6,150	9,374
21-25	808	808	18,191	7,231	18,500	8,977	16,044	10,812	18,849	12,045
25-30	0	0	2,506	0	4,695	808	13,976	2,515	15,022	7,580
31-35	0	0	0	0	0	0	808	808	2,074	1,808
36-40	0	0	0	0	0	0	0	0	0	1,257
>40	0	0	0	0	0	0	0	0	808	808
Total	44,285	44,285	44,285	44,285	44,285	44,285	44,285	44,285	44,285	44,285

W=With Diversion, WO=Without Diversion.

[a] Total days are equal to the sum of days for land to become inundated, days of inundation, and 10-day dry-down period. Total days until the effects of flood are gone are NOT equivalent to planting delays.

Another way to examine how the staging area may create planting delays is to examine the difference in days (i.e., days from activation until regional planting starts) between the two conditions. The difference between With and Without Diversion conditions represents the additional time that the land requires for the effects of flooding to be gone due to the Diversion. The extra days attributable to the Diversion may not result in planting delays because planting delays will depend upon when the flood event occurs, duration of the flood event, and when regional planting activity begins. However, the difference in time required for the effects of flooding to be gone between existing conditions and With the Diversion helps to clarify the magnitude of *potential* delays (Table 25).

In a 10-year event, only a relatively small amount of land would experience a longer period for the effects of flooding to be gone due to the Diversion (Table 25, Figure 36). In a 25-year event, the difference in time required for the effects of flooding to be gone due to the Diversion varies from 1 day to 23 days (Table 25, Figure 37). The difference in the time for the effects of flooding to be over varies from 0.5 day to 23.5 days in a 50-year event (Table 25, Figure 38). Similarly, in a 100-year event the difference in when the effects of flooding are over ranges from -0.5 days to 24.5 days (Table 25, Figure 39). The 500-year event has storage areas that have a potential for the effects of flooding to be over 3 days sooner With the Diversion to 24.5 days later With the Diversion (Table 25, Figure 40). Data presented in Table 25 and Figures 36 to 40 represent the difference in the time required for the effects of flooding to be gone, but do not represent planting delays.

Table 25. Difference in Days Required for Effects of Flooding to be gone between Existing Conditions and With the Diversion

Difference in Total Days[a]	Size of Flood Event				
	10-Year	25-Year	50-Year	100-Year	500-Year
	------ acres of storage areas ------				
- days[b]	1,918	0	0	808	6,285
0	40,905	14,626	9,799	4,544	4,058
1 to 5	849	14,750	19,086	18,105	22,653
6 to 10	0	3,431	1,906	6,341	1,258
11 to 15	0	0	638	0	0
16 to 20	0	7,318	8,215	6,273	2,728
21 to 25	0	4,160	4,641	8,214	7,303
>25	0	0	0	0	0
Total	44,285	44,285	44,285	44,285	44,285

[a] Total days for the effects of flooding to be over With the Diversion less the total days for the effects of flooding to be gone Without the Diversion. Total days are equal to the sum of days for land to become inundated, days of inundation, and 10-day dry-down period.

[b] Situations where total days are fewer With the Diversion than Without the Diversion.

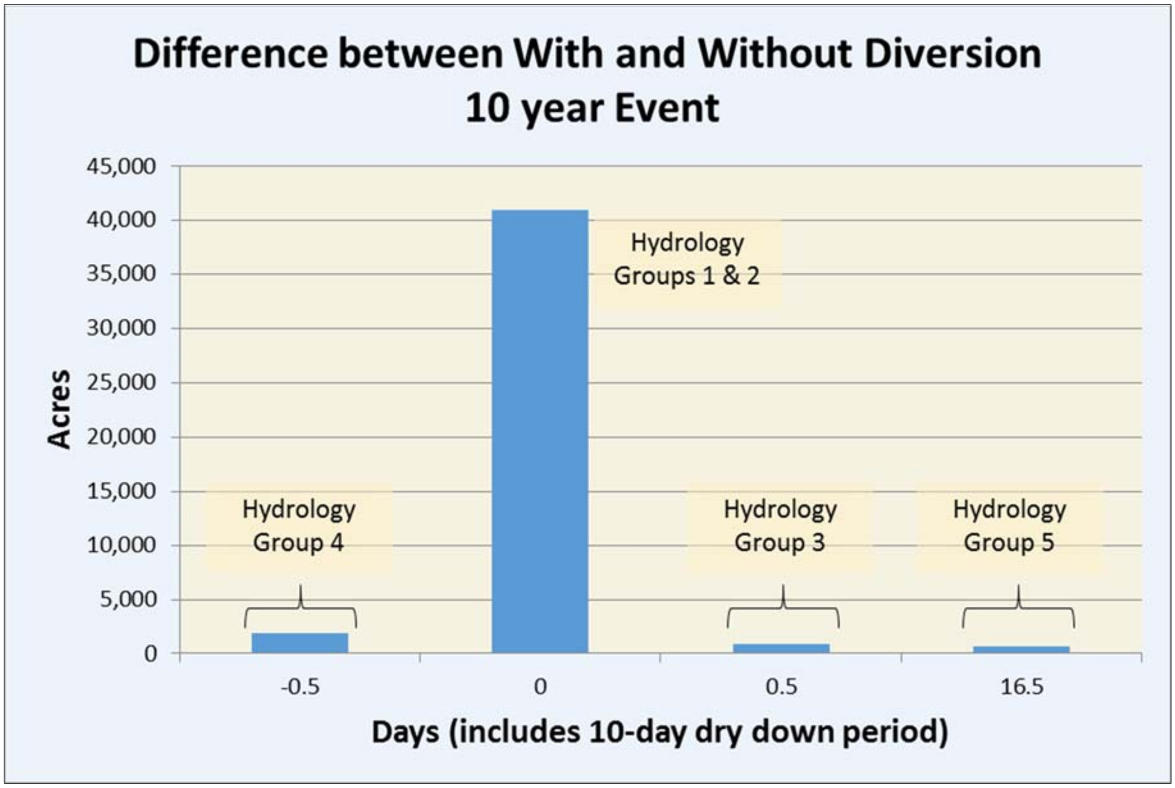

Figure 36. Extra Days needed for the Effects of Flooding to be gone due to the Diversion, 10-year Event

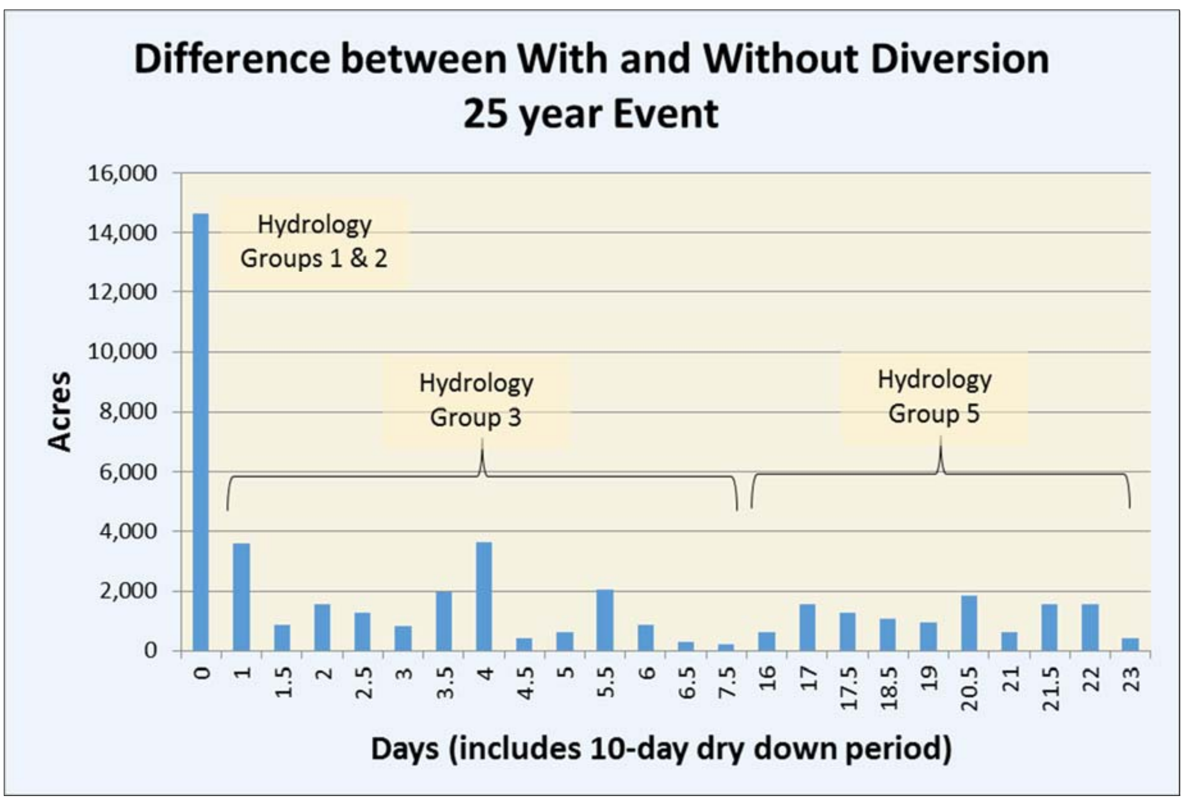

Figure 37. Extra Days needed for the Effects of Flooding to be gone due to the Diversion, 25-year Event

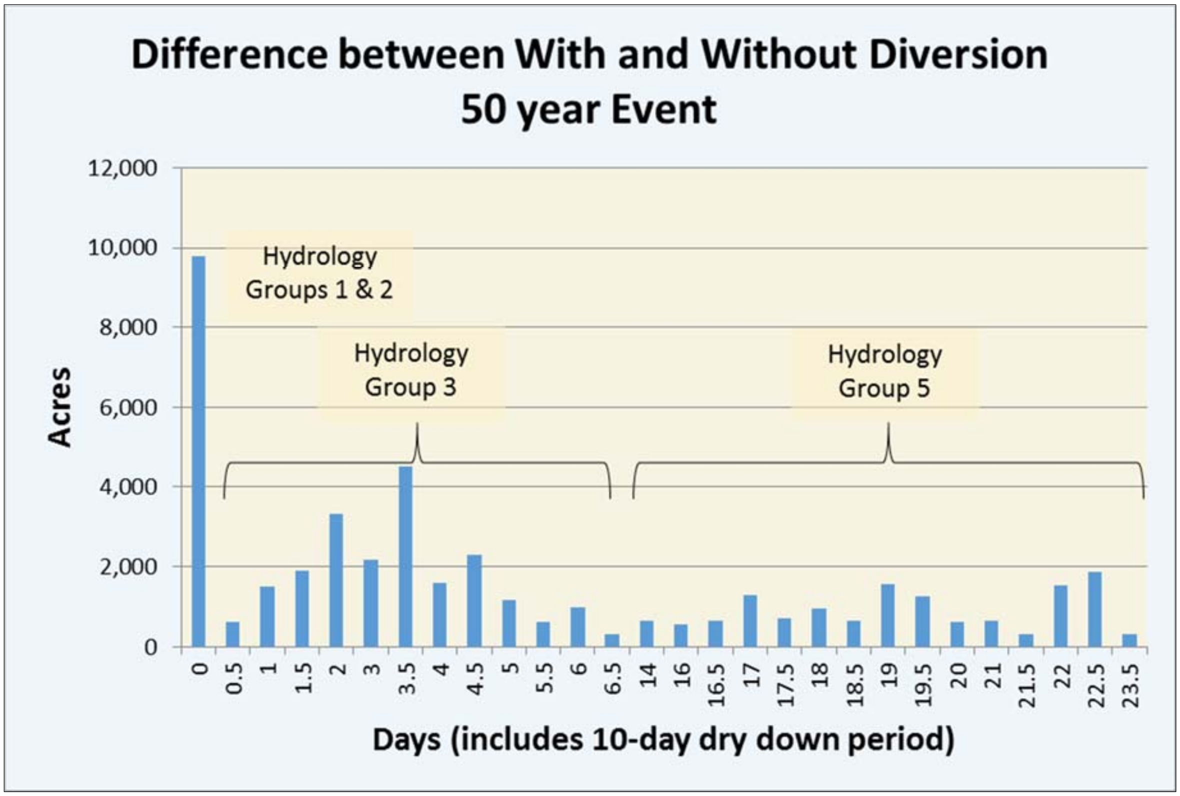

Figure 38. Extra Days needed for the Effects of Flooding to be gone due to the Diversion, 50-year Event

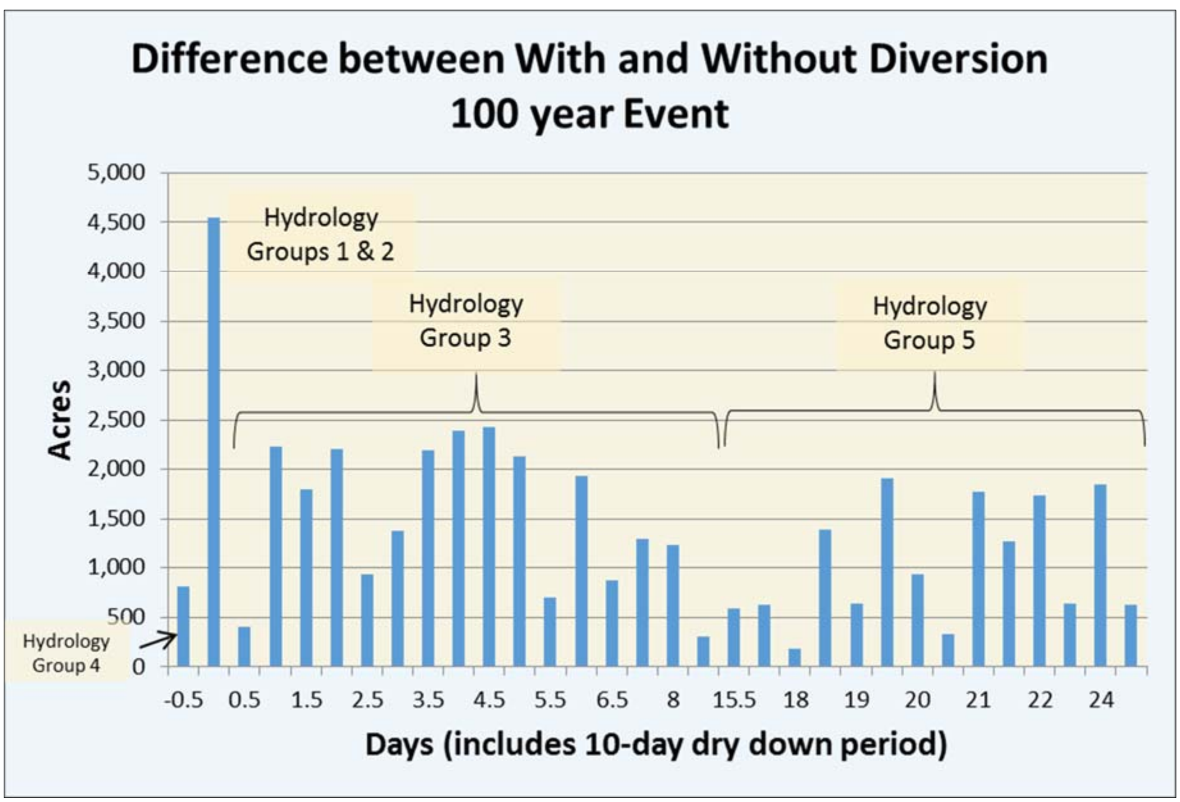

Figure 39. Extra Days needed for the Effects of Flooding to be gone due to the Diversion, 100-year Event

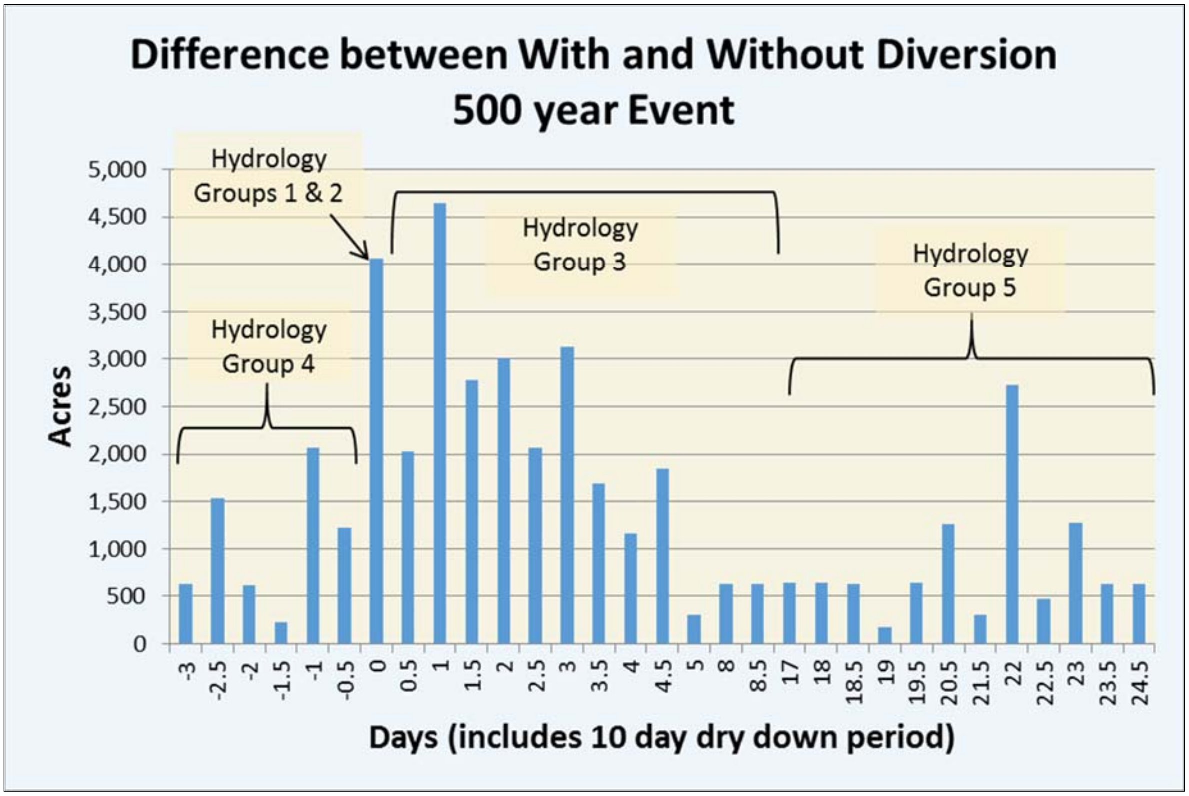

Figure 40. Extra Days needed for the Effects of Flooding to be gone due to the Diversion, 500-year Event

The time required for the effects of flooding to be gone in the staging area, With or Without the Diversion, varies from 0 days to more than 40 days during a flood event (see Table 24). Essentially, lands in the staging area would experience a wide range of days for the effects of flooding to be gone in either condition. This suggests that natural flooding would affect a substantial amount of acreage within the staging area. Also, the general time required for the effects of flooding to be gone and the acreages affected increases with flood event size for both existing conditions and With the Diversion (see Table 24).

Comparing the results in Table 24 with the results in Table 26, it is clear that during flood years a high probability exists that lands in the staging area will experience delayed planting for sugarbeets, corn, and wheat. For example, in Table 24, nearly 30,000 acres will require 16 to 25 days for the effects of flooding to be gone in a 50-year flood event With the Diversion and nearly 20,000 acres will require the same period for the effects of flooding to be gone with existing conditions. Correspondingly, in Table 26, a period of 16 to 20 days would result in a planting delay 40 percent of the time and a period of 21 to 25 days would result in planting delays nearly 60 percent of the time. In a 50-year flood event, the majority of acres (either Without or With the Diversion) would have a 40 to 60 percent chance of experiencing a planting delay. The probability of a planting delay increases with the size of the flood event, both for existing conditions and With the Diversion. Therefore, modeling based off of the existing data suggests that planting delays are highly probable for the majority of acres in the staging area. However, it must be stressed that the analysis is focused solely on the degree of planting delays caused by the Diversion.

Comparing the results in Table 24 to the results in Table 26, some potential exists that lands in the staging area could experience delayed planting for soybeans. In Table 24, about 2,900 acres will require 30 or more days for the effects of flooding to be gone With the Diversion and 3,900 acres will require the same period with existing conditions. In Table 27 lands that would require 40 or more days for the effects of planting to be gone would experience a planting delay 64 percent of the time. However, the majority of land will require 25 or fewer days for the effects of flooding to be gone With the Diversion or with existing conditions (Table 24), which suggests a low probability of planting delays for soybeans (Table 27). If the time for the effects of flooding to be over is 25 or fewer days after the staging area is triggered, the chance of planting delays for soybeans is around 3 percent. Table 27 indicates that lands would need to have 35 or more days for the effects of flooding to be over after staging area activation to have a greater than 50 percent chance for planting delays for soybeans.

Table 26. Comparing the Days until the Effects of Flooding are Over with the Days from Staging Activation until Regional Planting Reaches 20 Percent Completion for Sugarbeets in North Dakota

Total Days From Staging Activation until Effects of Flooding are over[a]	Annual Chance that Regional Planting Start Date would occur Prior to When Effects of Flooding are over[b]	Annual Chance that Effects of Flooding are over before Regional Plant Date[b]
-------- days --------	------------------------ percent ------------------------	
0	0	100
1-15	22.6	77.4
16-20	40.8	59.2
21-25	59.6	40.4
25-30	80.9	19.1
31-35	91.6	8.4
36-40	98.1	1.9
41-45	99.8	0.2
>45	100	0

[a] Total days are equal to days for land to become inundated, days of inundation, and 10-day dry-down period. Total days until the effects of flooding are over are NOT equivalent to planting delays.
[b] Based on the 10,000 replications from the Monte Carlo simulation. Regional planting start date is when regional planting has reached 20 percent completion.

Table 27. Comparing the Days until the Effects of Flooding are over the Days from Staging Activation until Regional Planting Reaches 20 Percent Completion for Soybeans in North Dakota

Total Days From Staging Activation until Effects of Flooding are over[a]	Annual Chance that Regional Planting Start Date would occur Prior to When the Effects of Flooding are over[b]	Annual Chance that Effects of Flooding are over before Regional Plant Date[b]
-------- days --------	------------------------ percent ------------------------	
0-15	0	100
16-20	0.3	99.7
21-25	2.7	97.3
26-30	14.7	85.3
31-35	31.4	68.6
36-40	64.0	36.0
41-45	82.1	17.9
46-50	96.0	4.0
>50	100	0

[a] Total days are equal to days for land to become inundated, days of inundation, and 10-day dry-down period. Total days until the effects of flooding are over are NOT equivalent to planting delays.
[b] Based on the 10,000 replications from the Monte Carlo simulation. Regional planting start date is when regional planting has reached 20 percent completion.

Summary of Planting Dates, Flood Start Dates, and Time Required for Effects of Flooding to be Gone

Inundated lands require a certain amount of time for the effects of flooding to be gone (i.e., water must leave the land and then it must dry-down). On the other end of the spectrum, there is a certain amount of time between when a flood event starts (i.e., 17,000 cfs in Fargo) to when regional planting typically begins. This section examined the number of days from when the staging area is activated to when the effects of flooding are over and compared that period to the number of days from flood event start (i.e., staging area activation) to when regional planting begins. Flood events result in delayed planting when inundated lands require more time for the effects of flooding to be gone than the time from flood event start to when regional planting begins. State alternatively, if regional planting begins before the effects of flooding are over for inundated lands, those lands will experience delayed planting. However, the analysis focused on 1) the additional time the Diversion adds to the time required for for the effects of flooding to be gone, and 2) how often those additional days are likely to result in planting delays. The following points below highlight the evaluation of flood start dates, time for effects of flooding to be over, and planting start dates.

-) Historical data suggest flood years do not necessarily result in a later planting start date than non-flood years for sugarbeets, corn, or wheat. Planting start dates for soybeans also show that planting start dates are nearly the same between flood years and non-flood years. Therefore, a flood year does not guarantee a later regional planting date than a non-flood year.

-) Historical data reveal that regional planting for sugarbeets, corn, and wheat has reached 20 percent completion between 19 to 38 days after Red River first reaches 17,000 cfs in Fargo. This is the range of days under which inundated lands have time for the effects of flooding to be gone before planting sugarbeets, corn, and wheat without incurring planting delays.

-) Historical data reveal that regional planting for soybeans has reached 20 percent completion between 31 to 58 days after the Red River first reaches 17,000 cfs in Fargo. This is the range of days under which inundated lands have time for the effects of flooding to be gone before planting soybeans without incurring planting delays.

-) Using historical data for corn, sugarbeets, and wheat, the Monte Carlo simulation revealed:
    -) a 40 percent annual chance that regional planting would begin within 20 days of the Red River reaching 17,000 cfs in Fargo
    -) a 40 percent annual chance that regional planting would begin between 21 to 30 days after Red River reached 17,000 cfs in Fargo
    -) 20 percent annual chance that regional planting would begin 30 or more days after the Red River reached 17,000 cfs in Fargo

-) Using historical data for soybeans, the Monte Carlo simulation revealed:
    -) a 37 percent annual chance that regional planting would begin within 35 days of the Red River reaching 17,000 cfs in Fargo
    -) a 37 percent annual chance that regional planting would begin between 36 to 42 days after Red River reached 17,000 cfs in Fargo
    -) 26 percent annual chance that regional planting would begin 43 or more days after the Red River reached 17,000 cfs in Fargo

-) Combining a dry-down period to the hydrology data revealed:

    -) A majority of acres within the staging area will require 16 to 25 days for the effects of flooding to be over after activation of the staging area, even though some storage areas will require over 30 days for the effects to be gone (Table 24)

    -) A majority of land in the staging area will flood Without the Diversion, and the Diversion will add 1 to 7 days of additional time for the effects of flooding to be over on those lands (Figures 36 to 40 and Table 25)

    -) Between 10,000 to 13,000 acres (depending upon flood event size) within the staging area will flood due to the diversion that would not otherwise flood, and the time for the effects of flooding to be over on those lands varies from 16 to 25 days after the activation of the staging area (Figures 36 to 40 and Table 25).

-) Examining the Monte Carlo distribution of regional planting start dates and distribution of flood event start dates reveals

    -) 60 percent annual chance that regional planting date for corn, soybeans, and wheat will be 21 or more days after the staging area is activated (Figure 31)

    -) 40 percent annual chance that regional planting date for corn, sugarbeets, and wheat will be 20 or fewer days after the staging area is activated (Figure 31)

    -) Annual probability ranges from 40 to 60 percent that the majority of acreage in the staging area, either with existing conditions or With the Diversion, would experience some planting delay for corn, sugarbeets, and wheat in a flood year (i.e., flood year of sufficient size to activate the staging area)

    -) 64 percent annual chance that regional planting date for soybeans will be more than 35 days after the staging area is activated.

    -) 31 percent annual chance that regional planting date for soybeans will be less than 35 days after the staging area is activated

    -) annual probability is less than 15 percent that the majority of acreage in the staging area would experience some planting delays for soybeans in a flood year

    -) The range of time needed for lands in the staging area to be ready for planting is similar to the amount of time between when the staging area is activated and when regional planting would start for corn, wheat, and sugarbeets, implying

        -) High probability of some planting delays for corn, wheat, and sugarbeets

        -) Low probability of large planting delays for corn, wheat, and sugarbeets

    -) The range of time needed for lands in the staging area to be ready for planting is shorter than the time between when the staging area is activated and when regional planting would start for soybeans, implying

        -) Low probability of planting delays for soybeans

Converting Planting Delays into Potential Revenue Losses

The potentially lost revenue resulting from planting delays is a function of optimal yields, yield declines, prices, planting start dates, and duration of planting period. The analysis begins with determining when planting can begin for a storage area by estimating the time required for the effects of flooding to be over, and comparing that date to when regional planting begins. If the total days from flood event start (i.e., measured as the sum of days to inundate, days of inundation, and a 10-day dry-down period) result in a calendar date that is earlier than the regional start date, that storage area would not experience any planting delays. However if the same condition results in a calendar date that is later than the regional start date, that storage area would experience planting delays.

The actual planting date for existing conditions (i.e., no Diversion) and With Diversion conditions are estimated for each storage area. The start date may be the same for With and Without Diversion, longer With the Diversion, or earlier With the Diversion (that is, the few situations when the Diversion creates faster water removal due to improved drainage capacity).

In some cases, a later planting start date between With and Without Diversion conditions may not necessarily result in reduced yields (see Scenario 1 in Figure 41). For there to be no yield loss with delayed planting, both start and end dates for planting have to occur during the optimal planting period. Since total potential revenue is estimated for both With and Without Diversion conditions, the effects of delayed planting become a function of the duration of planting and difference in start dates (Figure 41). Yield losses can be different even with the same planting period and same days of delay (compare scenario 1 to scenario 2 and compare scenario 3 to scenario 4 in Figure 41) if the planting start dates are different. Effects of planting delays also can be influenced by length of the planting period (compare scenario 2 to scenario 4 in Figure 41).

The number of variables that affect the degree of revenue loss from planting delays prevents providing a quick listing of the losses. Rather, daily revenues for corn, wheat, sugarbeets, and soybeans for Cass, Richland, Clay, and Wilken Counties have been placed in Appendix F. By summing the total revenues over the planting period and dividing by the number of days (demonstrated at the bottom of Figure 41), the tables in Appendix F can be used to estimate the average per-acre revenue loss based on different start dates and planting periods.

				Scenario 1		Scenario 2		Scenario 3		Scenario 4	
			Planting Period (days)	14		14		10		10	
			Delay due to Diversion (days)	3		3		5		5	
	Date	Bu/ac	$/ac	Planting without Diversion	Planting with Diversion	Planting without Diversion	Planting with Diversion	Planting without Diversion	Planting with Diversion	Planting without Diversion	Planting with Diversion
Optimal Planting Period	4/15	142.01	$618.31	$618.31							
	4/16	142.01	$618.31	$618.31							
	4/17	142.01	$618.31	$618.31							
	4/18	142.01	$618.31	$618.31	$618.31						
	4/19	142.01	$618.31	$618.31	$618.31						
	4/20	142.01	$618.31	$618.31	$618.31						
	4/21	142.01	$618.31	$618.31	$618.31						
	4/22	142.01	$618.31	$618.31	$618.31						
	4/23	142.01	$618.31	$618.31	$618.31	$618.31				$618.31	
	4/24	142.01	$618.31	$618.31	$618.31	$618.31				$618.31	
	4/25	142.01	$618.31	$618.31	$618.31	$618.31				$618.31	
	4/26	142.01	$618.31	$618.31	$618.31	$618.31	$618.31			$618.31	
	4/27	142.01	$618.31	$618.31	$618.31	$618.31	$618.31			$618.31	
	4/28	142.01	$618.31	$618.31	$618.31	$618.31	$618.31			$618.31	$618.31
	4/29	142.01	$618.31		$618.31	$618.31	$618.31			$618.31	$618.31
	4/30	142.01	$618.31		$618.31	$618.31	$618.31			$618.31	$618.31
	5/1	142.01	$618.31		$618.31	$618.31	$618.31			$618.31	$618.31
Non Optimal Planting Period	5/2	141.3	$615.18			$615.18	$615.18	$615.18		$615.18	$615.18
	5/3	140.6	$612.09			$612.09	$612.09	$612.09			$612.09
	5/4	139.9	$608.99			$608.99	$608.99	$608.99			$608.99
	5/5	139.2	$605.90			$605.90	$605.90	$605.90			$605.90
	5/6	138.5	$602.81			$602.81	$602.81	$602.81			$602.81
	5/7	137.7	$599.72				$599.72	$599.72	$599.72		$599.72
	5/8	137.0	$596.63				$596.63	$596.63	$596.63		
	5/9	136.3	$593.54				$593.54	$593.54	$593.54		
	5/10	135.6	$590.45					$590.45	$590.45		
	5/11	134.1	$583.80					$583.80	$583.80		
	5/12	132.6	$577.15						$577.15		
	5/13	131.0	$570.51						$570.51		
	5/14	129.5	$563.86						$563.86		
	5/15	128.0	$557.21						$557.21		
	5/16	126.5	$550.57						$550.57		
	5/17	124.9	$543.92								
	5/18	123.4	$537.27								
	//	//	//								
	5/30	93.7	$408.06								
	5/31	91.1	$396.46								
	6/1 Corn switched to Soybeans or Prevent Plant										
				Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Gross Revenue				$8,656	$8,656	$8,610	$8,545	$6,009	$5,783	$6,180	$6,118
Difference in Gross Revenues					$0.00		-$65.05		-$225.67		-$62.04
Average Per Acre					$0.00		-$4.65		-$22.57		-$6.20

Planting Start Dates

Figure 41. Illustration of How Revenue Losses from Planting Delays are Subject to Planting Start Dates, Days of Delay, and Length of Planting Period, Corn, Cass County.

Revenues for each storage area represent a composite of corn, wheat, soybeans and sugarbeets, based on the respective county's crop rotation percentage (Table 28). Subtracting the difference in revenue potential between the two conditions, and dividing by the total acres in the storage area provides an estimated per-acre potential revenue loss (Table 28).

Storage area WRSA353 was selected to illustraite how potential revenues are estimated and how per-acre losses are determined. WRSA353 has 292 acres. For the study, all storage areas were allocated a percentage of corn, wheat, soybeans, and sugarbeets. WRSA353 was modeled to have 101.29 acres in corn, 26.10 acres in wheat, 158.44 acres in soybeans, and 6.17 acres in sugarbeets (see Table 4 for crop rotation percentages by county).

The hydrology of WRSA353 for a 25-year flood event is that the storage area would not flood Without the diversion but would be inundated using the Diversion staging area this is an example of (Hydrology Group 5). The regional planting start date for the replication in Table 28 is April 15th. However, With the Diversion, the effects of flooding would not be over for that land until April 18th based on the storage area requiring 19 days for the effects of flooding to be over (both regional planting start date and flood date are based on Monte Carlo simulation whereas 19 days for the effects of flooding to be over is based on the hydrology data) a staging activation date of March 30th.

While the storage area requires 19 days from staging activation until the effects of flooding are over (based on when regional planting reaches 20 percent completion), this situation results in only a three-day planting delay for corn, wheat, and sugarbeets. No planting delays exist for soybeans as the regional planting date of May 8th falls substantially after April 18th (earliest date when the effects of flooding are gone). The planting period (number of days from start to end) varies for corn, wheat, soybeans and sugarbeets (those rates are allowed to vary within the Monte Carol simulation). While corn, wheat, and sugarbeets have nearly identical end dates for the last day of optimal planting (see Figure 21), the revenue effects of delayed planting are different among those three crops. The three-day planting delay did not create any revenue differences for corn as the crop was planted entirely within the optimal planting window for both the With and Without Diversion conditions. However, based on the regional planting start date and duration of the planting period, both wheat and sugarbeets experienced some days of planting during the non-optimal period (i.e., when yields begin to decline). The delay of three days for wheat and sugarbeets subtracted three days of planting from the optimal period and added three days of planting during the non-optimal period.

Total revenues are summed for each crop for the With Diversion and Without Diversion conditions. The difference in revenue represents the effect of the three-day planting delay. When the total acres of all crops are considered, the decline in revenues for wheat and sugarbeets must be averaged with the acres of corn and soybeans. The overall loss for the storage area is not substantial, as the reductions in revenues for wheat and sugarbeets were modest, and 89 percent of the storage area acreage (corn and soybeans) had no revenue losses.

Essentially, the Monte Carlo simulation repeats the above analysis using different combinations of flood event start dates, regional planting dates, and planting rates for the five flood events. A total of 10,000 replications comprise the Monte Carlo simulation.

Table 28. Demonstration of How Potential Lost Revenues are Generated, using WRSA353 Storage Area as an Example in a 25-year Flood Event								
	Wheat		Corn		Soybeans		Sugarbeets	
	WO	W	WO	W	WO	W	WO	W
Staging Area Activated		Mar 30		Mar 30		Mar 30		Mar 30
Regional Planting Start Date	Apr 15	Apr 15	Apr 15	Apr 15	May 8	May 8	Apr 15	Apr 15
Days After Staging Area Activation for Effects of Flooding to be gone	na	19	na	19	na	19	Na	19
Planting Start Date for for Each Crop	Apr 15	Apr 18	Apr 15	Apr 18	May 8	May 8	Apr 15	Apr 18
Days of Planting Delay	0	3	0	3	0	0	0	3
Planting End Dates	May 6	May 9	Apr 27	Apr 30	May 20	May 20	May 4	May 7
Days of Optimal Planting	16	13	13	13	13	13	16	13
Days of Non-Optimal Planting	6	9	0	0	0	0	4	7
Total Revenue ($)	10,236	10,047	62,630	62,630	69,401	69,401	7,878	7,805
Difference in Total Revenue by Crop	-188.86		0		0		-72.40	
Rotation Percentage	8.9		34.9		54.3		2.1	
Total Acres per Crop	26.10		101.92		158.44		6.17	
Difference in Total Revenue per Acre	-7.24		0		0		-11.74	
Revenue Difference Per Acre for Storage Area	Total Losses / Total Acres (-188.86+0+0+-72.40) / 292 = -0.89/acre							
Table Notes: Storage area WRSA353 is in Cass County, North Dakota. Size is 292 acres. WO = Without Diversion W = With Diversion. WRSA353 is in Hydrology Group 5 meaning it does not flood with existing conditions but would flood With the Diversion during a 25-year flood event. Results in the table represent one actual replication out of the 10,000 replications developed for the study. Days of optimal and non-optimal planting based on planting start dates and agronomic dates for each crop (see Figure 21). Revenues represent a total of yield x price over the planting period (see Appendix F). Yields represent target yields, along with yield declines occurring after optimal planting (see Appendix F).								

Evaluation of 10-year, 25-year, 50-year, 100-year, and 500-year Flood Events

Two key elements to the analysis are 1) how likely are damages to occur during a flood year and 2) what is the dollar value of those losses. The following results combine the elements discussed in the previous two sections; how the time for the effects of flooding to be gone overlaps with when regional planting will begin and how the delayed planting results in revenue losses.

Probability of Losses During a Flood Event

No two flood events are the same nor are spring planting conditions homogeneous across years. Therefore, it becomes difficult to predict a point estimate of the potential effects of water storage on planting operations, which is precisely the reason for conducting a simulation over a range of different conditions. The analysis estimates how frequent revenues losses occur over the range of different flood event start dates, planting start dates, and planting rates for each storage area in the five flood events. Storage areas that do not flood or flood the same duration would not be impacted by the staging area, so the emphasis on estimating flood-related revenue losses can be focused on those storage areas that flood longer With the Diversion (Group 3) and those storage areas that now flood with use of the staging area but would not otherwise experience a spring flood event (Group 5).

-) 10-year Flood Event

In a 10-year event, storage areas that are inundated longer With the Diversion have a 33 percent annual probability of incurring planting delays that result in revenue declines (Tables 29 and 30). Not all planting delays result in revenue losses (see Table 28), so the annual probability of experiencing a planting delay is greater than the annual chance of experiencing a revenue loss. Hydrology Group 3 storage areas have a 66 percent annual chance of experiencing no losses associated With the Diversion in a 10-year event. Similarly, Hydrology Group 5 storage areas have a 29 percent annual chance of incurring revenues losses associated with operation of the staging area in a 10-year event. Alternatively, about 70 percent of the time Hydrology Group 5 storage areas would not experience revenues losses in a 10-year event. Storage areas that are modeled to have reduced periods of inundation (Hydrology Group 4) resulting from the Diversion have a 41 percent annual probability of improved revenues associated with earlier planting start dates. While the results show no revenue losses for storage areas in Hydrology Group 2, the revenue losses being measured are those created by the Diversion. Results should be interpreted carefully, as the model does not imply that Hydrology Group 2 storage areas have no revenue losses from delay planting—rather, since the flood duration is the same, the Diversion did not create revenue losses.

For storage areas in Groups 3 and 5, the average per-acre losses are expected to range from $1 to $25 in nearly all situations that produce a revenue loss from delayed planting (Table 29). Losses greater than $25 per acre are possible, just less likely. In an attempt to more accurately portray the average revenue reductions, Hydrology Groups 3 and 5 were further delineated into sub-groups based on the difference between existing conditions and With Diversion conditions for the days required for the effects of flooding to be gone (Table 30). Proper interpretation of the revenue losses must consider that all storage areas within a particular hydrology group (and sub-group) are averaged, and all acres within each individual storage area also are averaged. [See the example illustrated in Table 28 for how acres within an individual storage area are averaged for each replication]. Averaging within the model results in storage areas with low losses being combined with storage areas having higher losses. For example, a storage area in Hydrology Group 3 that requires 1 additional day for the effects of flooding to be over would be averaged with a storage area that requires 5 additional days for the effects of flooding to be gone. The average revenue loss reported therefore would be higher than the storage area with 1 day of delay and lower than the storage area with 5 days of delay.

-) 25-year Flood Event

Only three hydrology groups are represented in a 25-year event. Hydrology Group 3 (floods longer) had a revenue loss in 63 percent of the replications. Storage areas in Hydrology Group 5 (now floods) have over a 50 percent annual chance of experiencing revenue losses (Table 31). Nearly all of the losses for storage areas in Hydrology Group 3 ranged from $1 to $25 per acre. Storage areas that now flood With the Diversion that would not normally flood had average damages greater than $25 per acre in about 8 percent of the replications, with the remainder of the potential revenue losses in the $1 to $25 per acre range. Storage areas in Hydrology Group 5 that had over 20 days of additional time required for the effects of flooding to be over experienced losses greater than $50 per acre in about 2 percent of the replications (Table 32).

-) 50-year Flood Event

Results for the 50-year event for storage areas in Hydrology Groups 3 and 5 were similar to those for the 25-year event (Table 33). Hydrology Group 3 experienced revenue losses ranging from $1 to $25 per acre in 67 percent of the replications. Revenue losses occurred in 56 percent of the replications for Hydrology Group 5, with nearly 8 percent over $25 per acre. When Groups 3 and 5 were delineated by days, the results became more sensitive to the length of time required for the effects of flooding to be over. One storage area in Hydrology Group 5, requiring 14 additional days from activation of the staging area to when the effects of flooding would be gone, only had revenue losses in 19 percent of the replications (Table 34). Storage areas requiring more than 20 days for the effects of flooding to be gone experienced revenue losses in 56 percent of the replications. The contrast in frequency of revenue losses between the storage areas with less than 14 days and more than 20 days is consistent with the results discussed in the Evaluation of Potential Planting Delays section.

-) 100-year Flood Event

In a 100-year flood event, storage areas in Hydrology Group 3 had revenue losses due to the Diversion in about 75 percent of the replications (Table 35). However, nearly all of the revenues losses for Hydrology Group 3 ranged from $1 to $25 per acre. Storage areas in Hydrology Group 5 had revenue losses in 60 percent of the replications. As was observed with the 50-year flood, storage areas having greater than 20 days difference in the time required for the effects of flooding to be gone experienced revenue losses considerably more often that storage areas requiring 16 to 20 days for the effects of flooding to be gone (Table 36). Longer periods for the effects of flooding to be gone (Group 5) also increased the likelihood of larger per-acre losses. Average losses in excess of $25 per acre occurred in 17 percent of the replications for storage areas with 20 or more additional days for the effects of flooding to be over compared to revenue losses in about 5 percent of the replications for storage areas requiring 16-20 additional days for the effects of flooding to be over.

-) 500-year Event Event

The likelihood of revenue losses for Hydrology Groups 3 and 5 for a 500-year event were similar to those for a 100-year event. Seventy-five percent of the replications produced revenue losses for storage areas that now flood longer With the Diversion, and nearly all of those losses ranged from $1 to $25 per acre (Table 37). Storage areas in Hydrology Group 5 exhibited revenue losses in 60 percent of the replications—nearly identical to the frequency of losses in the 100-year event. Hydrology modeling revealed reduced water inundation periods for several storage areas in a 500-year event. Those storages areas (Hydrology Group 4) experienced revenue gains in 94 percent of the replications. The likelihood of greater revenue losses increased in the 500-year event over those observed in the other flood events. In Hydrology Group 3, those storage areas With 6 to 10 additional days for the effects of flooding to be over had a 28 percent change of revenue losses exceeding $25 per acre. The percentage for replications producing losses of the same magnitude for the storage areas with similar hydrology in the 100-year event was 20 percent. The 500-year event produced some situations where the average per-acre losses within the storage areas exceeded $75 per acre (Table 38).

Table 29. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 10-year Flood Event

Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------ Based on 10,000 replications from Monte Carlo Simulation ------------------------------							
(1) Does not flood	100%	0%	0%			0%	0%	31,784
(2) Floods Same Duration	100%	0%	0%			0%	0%	9,121
(3) Floods Longer Duration	66.8%	33.2%	0%			0%	33.2%	849
(4) Floods Shorter Duration	59.1%	0%	0%			40.9%	0%	1,918
(5) Now Floods With Diversion	70.5%	28.9%	0.6%			0%	29.5%	613

[a] The range of losses per acre represent an average of all storage areas with the hydrology group.

Table 30. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 10-year Flood Event

	Time from Activation of Staging Area until Effects of Flooding are Over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres
	-------------------- days --------------------			------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------						
3	16.5	17.0	1 to 5	66.8%	33.2%	0%	0%	0%	33.2%	849
3	Na	na	6 to 10	na	na	na	na	na	na	na
5	Na	na	11 to 15	na	na	na	na	na	na	na
5	0	16.5	16 to 20	70.5%	28.9%	0.6%	0%	0%	29.5%	613
5	Na	na	Over 20	na	na	na	na	na	na	na

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Table 31. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 25-year Flood Event

Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------ Based on 10,000 replications from Monte Carlo Simulation ------------------------------							
(1) Does not flood	100%	0%	0%	0%	0%	0%	0%	13,900
(2) Floods Same Duration	na	na	na	na	na	na	na	na
(3) Floods Longer Duration	36.4%	63.6%	0%	0%	0%	0%	63.6%	18,907
(4) Floods Shorter Duration	na	na	na	na	na	na	na	na
(5) Now Floods With Diversion	47.5%	45.0%	6.8%	0.7%	0.1%	0%	52.5%	11,478

Na=not applicable. There were no storage areas in those hydrology groups.

[a] The range of losses per acre represent an average of all storage areas with the hydrology group.

Table 32. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 25-year Flood Event

	Time from Activation of Staging Area until Effects of Flooding are Over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres
	-------------------- days --------------------			------------------------ Based on 10,000 replications from Monte Carlo Simulation ------------------------						
3	19.8	22.8	1 to 5	36.4%	63.6%	0%	0%	0%	63.6%	14,750
3	16.4	22.4	6 to 10	40.2%	57.8%	2.0%	0%	0%	59.8%	3,431
5	na	na	11 to 15	na	na	na	na	na	na	na
5	0	18.0	16 to 20	63.1%	33.4%	3.2%	0.3%	0%	36.9%	5,471
5	0	21.4	Over 20	47.4%	40.2%	10.6%	1.6%	0.1%	52.6%	6,007

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Table 33. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 50-year Flood Event								
Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------ Based on 10,000 replications from Monte Carlo Simulation ------------------------------							
(1) Does not flood	100%	0%	0%	0%	0%	0%	0%	8,991
(2) Floods Same Duration	100%	0%	0%	0%	0%	0%	0%	808
(3) Floods Longer Duration	32.6%	67.4%	0%	0%	0%	0%	67.4%	20,992
(4) Floods Shorter Duration	na	na	na	na	na	na	na	na
(5) Now Floods With Diversion	43.8%	48.4%	6.8%	0.8%	0.1%	0.0%	56.2%	13,494

Na=not applicable. There were no storage areas in those hydrology groups.

[a] The range of losses per acre represent an average of all storage areas with the hydrology group.

Table 34. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion,50-year Flood Event										
	Time from Activation of Staging Area until Effects of Flooding are Over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres
	-------------------- days --------------------			------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------						
3	20.3	23.3	1 to 5	32.6%	67.4%	0.0%	0.0%	0.0%	67.4%	19,086
3	17.2	23.2	6 to 10	43.8%	53.7%	2.4%	0.0%	0.0%	56.2%	1,906
5	0	14.0	11 to 15	80.7%	18.2%	1.1%	0.0%	0.0%	19.3%	638
5	0	17.8	16 to 20	59.1%	36.0%	4.5%	0.5%	0.0%	40.9%	8,215
5	0	22.2	Over 20	43.9%	40.6%	13.1%	2.2%	0.2%	56.1%	4,641

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Table 35. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 100-year Flood Event								
Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------------							
(1) Does not flood	100%	0%	0%	0%	0%	0%	0%	3,918
(2) Floods Same Duration	100%	0%	0%	0%	0%	0%	0%	626
(3) Floods Longer Duration	25.4%	74.6%	0.1%	0%	0%	0%	74.6%	24,446
(4) Floods Shorter Duration[b]	100%	0%	0%	0%	0%	0%	0%	808
(5) Now Floods With Diversion	40.3%	48.3%	9.8%	1.5%	0.1%	0%	59.8%	14,487

Na=not applicable. There were no storage areas in those hydrology groups.

[a] The range of losses per acre represent an average of all storage areas with the hydrology group.

[b] The one storage area having a 0.5 day improvement in flood duration did not produce positive economic effects due to rounding to whole days within the model.

Table 36. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion,100-year Flood Event										
	Time from Activation of Staging Area until Effects of Flooding are Over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres
	-------------------- days --------------------			------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------						
3	21.4	24.5	1 to 5	25.4%	74.6%	0.0%	0.0%	0.0%	74.6%	18,105
3	18.4	25.1	6 to 10	28.9%	51.6%	19.6%	0.0%	0.0%	71.2%	6,341
5	na	na	11 to 15	na	na	na	na	na	na	na
5	0	18.7	16 to 20	59.1%	35.6%	4.8%	0.5%	0.0%	40.9%	6,273
5	0	22.6	Over 20	40.2%	42.7%	14.1%	2.6%	0.3%	59.8%	8,214

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Table 37. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 500-year Flood Event

Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------------							
(1) Does not flood	100%	0%	0%	0%	0%	0%	0%	1,382
(2) Floods Same Duration	100%	0%	0%	0%	0%	0%	0%	2,676
(3) Floods Longer Duration	25.4%	74.5%	0%	0%	0%	0%	74.6%	23,911
(4) Floods Shorter Duration[b]	5.6%	0%	0%	0%	0%	94.4%	0%	6,285
(5) Now Floods With Diversion	40.2%	45.9%	11.7%	1.9%	0.2%	0%	59.8%	10,031

Na=not applicable. There were no storage areas in those hydrology groups.

[a] The range of losses per acre represent an average of all storage areas with the hydrology group.

[b] The one storage area having a 0.5 day improvement in flood duration did not produce positive economic effects due to rounding to whole days within the model.

Table 38. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion,500-year Flood Event

	Time from Activation of Staging Area until Effects of Flooding are Over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres
	-------------------- days --------------------			------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------						
3	21.6	23.8	1 to 5	25.4%	74.5%	0.0%	0.0%	0.0%	74.6%	22,653
3	16.5	24.8	6 to 10	40.2%	32.1%	27.2%	0.4%	0.0%	59.8%	1,258
5	na	na	11 to 15	na	na	na	na	na	na	na
5	0	18.4	16 to 20	59.1%	36.4%	4.1%	0.4%	0.0%	40.9%	2,728
5	0	22.2	Over 20	40.2%	41.7%	14.6%	2.9%	0.4%	59.8%	7,303

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Gross Revenues per Acre With and Without Diversion

The gross revenues per acre were averaged over all 10,000 replications for the five hydrology groups for each of the five flood events. In addition to average revenues, the minimum and maximum observed gross revenues were included to provide some perspective on the potential range of observed revenues for the different hydrology groups. The gross revenues are subject to the price and target yield assumptions, and the yield decline functions used in the model.

-) 10-year Flood Event

The average gross revenue for Hydrology Groups 3, 4, and 5 for the Without and With Diversion conditions are nearly identical in the 10-year event (Table 39). Storage areas that do not flood averaged $588 of gross revenue per acre, which represents all of the combinations of early and late spring planting conditions but does not include any effects from either natural flooding or Diversion-related flooding. An overall average of $588 per acre is a direct function of the target yields, prices, crop rotation, distribution of planting start dates and associated yield decline functions.

Hydrology Groups 2, 3, and 4 can be compared to Hydrology Group 1 to indicate the effects of natural flooding, as storage areas in Hydrology Groups 2, 3, and 4 are inundated with spring water Without the Diversion. The average revenues for those groups are lower than the average revenues for the storage areas that do not flood, demonstrating that natural spring flooding does create revenue losses through delayed planting when evaluated over a wide range of potential planting conditions. The average gross revenue among those three groups is not equal because the duration of water inundation (natural flooding) varies among the groups (see Appendix C).

The difference in gross revenues between With and Without Diversion for the hydrology groups affected by flooding is very small, suggesting the overall effects of the Diversion in a 10-year event are minimal (Tables 39 and 40). As was highlighted in the previous section, the percentage of replications in a 10-year event that resulted in no revenue loss ranged from 67 percent to 71 percent for Hydrology Groups 3 and 5, respectively. Part of the reason for the small differences between the With and Without Diversion conditions is the high number of no-loss situations.

-) 25-year Flood Event

In the 25-year flood event Without the Diversion, the average gross revenue for Hydrology Group 3 ($532) was lower than Hydrology Group 5 ($588) (Table 41). The difference clearly highlights that natural flooding creates revenue losses due to delay planting. The difference in gross revenue between Hydrology Groups 1 and 5 (both groups do not currently flood), Without the Diversion, are the result of different composition of acres among the four counties in the staging area. Revenues among the four counties are different, due to different yields and crop shares.

The difference in gross revenues for storage areas in Hydrology Group 3 having 1 to 5 days additional delay compared to storage areas with 6 to 10 days additional delay is attributable to the overall time required for the effects of flooding to be over in those storage areas. For example Without the Diversion, the total days required for the effects of flooding to be gone for Hydrology Group 3 that has 1 to 5 days of delay is 3 days longer than the requirements for storage areas in Hydrology Group 3 that have 6 to 10 days of additional delay (see Table 32). The difference in average gross revenue between the two sub-groups in Hydrology Group 3 is partially due to the difference in total time required for the effects of flooding to be over, and that the group with 6 to 10 days is heavily weighted by acreage in Clay County, which has higher relative gross revenues per acre than Cass County.

-) 50-year Flood Event

Only three hydrology groups are represented in a 50-year event. Hydrology Group 3 (floods longer) had average revenue loss around $4 per acre when all replications were averaged (i.e., an average of no losses were included). Storage areas in Hydrology Group 5 (floods With Diversion) had average revenue loss around $6.50 per acre ($601.80 per acre Without Diversion compared to $595.30 per acre With Diversion) when all replications were averaged (Table 43). For Hydrology Group 3, the storage areas with 6 to 10 days of additional delay had average revenue losses over all simulated conditions of $7.85 per acre compared to around $4 for storage areas with 1 to 5 days of additional delay. Similarly, the average losses per acre over all possible combination in the simulation for storage areas in Hydrology Group 5 ranged from $1.60 to $10.20 per acre (Table 44).

-) 100-year Flood Event

All five hydrology groups are represented in a 100-year event. The average gross revenue for storage areas that flood the same duration With and Without the Diversion were nearly $110 per acre less than storage areas that do not flood (Table 45). While the lower revenues of $110 per acre cannot be attributed to the Diversion, it does demonstrate the potential revenue losses associated with planting delays (see Appendix C for average days water in on the land for Hydrology Group 2). Similarly, storage areas that are expected to flood shorter With the Diversion (Group 4) also demonstrated revenue differences when compared to storage areas that do not flood (Group 1), which is due to the duration of water inundation on those areas (see Appendix C).

Storage areas in Hydrology Group 3 (1 to 5 additional days) had average gross revenues $6 less With the Diversion and those storage areas with 6 to 10 additional days had average gross revenues that were $17.20 lower With the Diversion. In Hydrology Group 5, gross revenues ranged from $12.40 lower for storage areas with 16-20 days for the effects of flooding to be gone after staging area activation to $18.40 lower With the Diversion for those areas that require more than 20 days for the effects of flooding to be over after activation of the staging area (Table 46).

-) 500-year Flood Event

Although a 500-year event is expected to be considerably larger than the other flood events, estimated average gross revenues were similar to the 100-year event (Tables 47 and 48). Much of the reason for having similar gross revenues to the 100-year event is that the additional duration of water storage is actually lower for many storage areas in the 500-year event (see Appendix C).

Table 39. Gross Revenues, by Hydrology Group, With and Without Diversion, 10-year Flood Event				
	Gross Revenues Per Acre[a]			
Hydrology Group	Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	587.88	439.20	618.71	25.31
(2) Floods Same Duration	538.55	394.30	567.54	20.91
(3) Floods Longer Duration	491.53	341.78	514.90	18.72
(4) Floods Shorter Duration	490.49	338.23	514.90	18.47
(5) Now Floods With Diversion	493.03	343.55	514.90	19.31
	With Diversion			
(1) Does not flood	587.88	439.20	618.71	25.31
(2) Floods Same Duration	538.55	394.30	567.54	20.91
(3) Floods Longer Duration	491.10	340.15	514.90	18.61
(4) Floods Shorter Duration	490.90	339.54	514.90	18.56
(5) Now Floods With Diversion	491.22	340.63	514.90	18.65

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 40. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 10-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	491.53	341.78	514.90	18.72
3	6 to 10	na	na	na	na
5	11 to 15	na	na	na	na
5	16 to 20	493.03	343.55	514.90	19.31
5	Over 20	na	na	na	na
		With Diversion			
3	1 to 5	491.10	340.15	514.90	18.61
3	6 to 10	na	na	na	na
5	11 to 15	na	na	na	na
5	16 to 20	491.22	340.63	514.90	18.65
5	Over 20	na	na	na	na

Na=not applicable. There were no storage areas in those hydrology groups.
[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 41. Gross Revenues, by Hydrology Group, With and Without Diversion, 25-year Flood Event

Hydrology Group	Gross Revenues Per Acre[a] Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	604.60	454.53	637.04	26.52
(2) Floods Same Duration	na	na	na	na
(3) Floods Longer Duration	532.35	388.71	561.83	20.18
(4) Floods Shorter Duration	na	na	na	na
(5) Now Floods With Diversion	587.57	440.68	618.98	25.62
	With Diversion			
(1) Does not flood	604.60	454.53	637.04	26.52
(2) Floods Same Duration	na	na	na	na
(3) Floods Longer Duration	528.69	379.25	561.83	19.71
(4) Floods Shorter Duration	na	na	na	na
(5) Now Floods With Diversion	581.14	439.45	618.98	23.16

Na=not applicable. There were no storage areas in those hydrology groups.
[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 42. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 25-year Flood Event

Hydrology Group	Difference in Total Days	Gross Revenues Per Acre[a] Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	516.15	367.76	544.04	19.15
3	6 to 10	578.70	434.69	612.55	23.81
5	11 to 15	na	na	na	na
5	16 to 20	587.61	440.25	618.86	25.53
5	Over 20	587.54	440.78	619.08	25.69
		With Diversion			
3	1 to 5	513.10	360.35	544.04	18.89
3	6 to 10	571.64	422.11	612.55	22.41
5	11 to 15	na	na	na	na
5	16 to 20	583.66	440.25	618.86	23.75
5	Over 20	578.84	430.29	619.08	22.97

Na=not applicable. There were no storage areas in those hydrology groups.
[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 43. Gross Revenues, by Hydrology Group, With and Without Diversion, 50-year Flood Event				
	Gross Revenues Per Acre[a]			
Hydrology Group	Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	597.12	446.70	628.51	25.78
(2) Floods Same Duration	na	na	na	na
(3) Floods Longer Duration	538.10	394.11	569.30	20.40
(4) Floods Shorter Duration	na	na	na	na
(5) Now Floods With Diversion	601.80	454.05	634.68	26.72
	With Diversion			
(1) Does not flood	597.12	446.70	628.51	25.78
(2) Floods Same Duration	na	na	na	na
(3) Floods Longer Duration	533.87	383.72	569.30	20.00
(4) Floods Shorter Duration	na	na	na	na
(5) Now Floods With Diversion	595.30	454.05	634.68	24.08

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

[b] Average of all 10,000 replications.

Table 44. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 50-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	534.44	389.38	565.35	20.15
3	6 to 10	574.75	431.23	608.84	23.39
5	11 to 15	619.24	470.77	654.03	28.15
5	16 to 20	604.35	456.20	637.42	26.88
5	Over 20	594.87	447.94	627.17	26.25
		With Diversion			
3	1 to 5	530.57	380.05	565.35	19.80
3	6 to 10	566.89	414.56	608.84	22.16
5	11 to 15	617.62	470.77	654.03	27.17
5	16 to 20	599.59	456.20	637.42	24.74
5	Over 20	584.64	433.58	627.17	23.25

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

[b] Average of all 10,000 replications.

Table 45. Gross Revenues, by Hydrology Group, With and Without Diversion, 100-year Flood Event				
	Gross Revenues Per Acre[a]			
Hydrology Group	Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	588.38	434.49	617.48	24.39
(2) Floods Same Duration	478.68	312.79	514.86	18.35
(3) Floods Longer Duration	549.67	407.11	583.82	20.91
(4) Floods Shorter Duration	470.80	305.68	513.99	18.42
(5) Now Floods With Diversion	599.16	451.52	631.75	26.50
	With Diversion			
(1) Does not flood	588.38	434.49	617.48	24.39
(2) Floods Same Duration	478.68	312.79	514.86	18.35
(3) Floods Longer Duration	543.21	392.62	583.80	20.39
(4) Floods Shorter Duration	470.80	305.68	513.99	18.42
(5) Now Floods With Diversion	590.73	446.09	631.75	23.54

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

[b] Average of all 10,000 replications.

Table 46. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 100-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	533.63	387.21	566.52	19.94
3	6 to 10	595.47	452.34	633.23	24.21
5	11 to 15	na	na	na	na
5	16 to 20	590.87	443.19	622.42	25.76
5	Over 20	605.49	457.87	638.87	27.07
		With Diversion			
3	1 to 5	529.19	377.31	566.49	19.65
3	6 to 10	583.26	436.33	633.23	22.82
5	11 to 15	na	na	na	na
5	16 to 20	585.80	443.19	622.42	23.66
5	Over 20	594.49	444.67	638.87	23.78

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

[b] Average of all 10,000 replications.

Table 47. Gross Revenues, by Hydrology Group, With and Without Diversion, 500-year Flood Event				
	Gross Revenues Per Acre[a]			
Hydrology Group	Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	$573.47	$416.98	$599.83	$22.72
(2) Floods Same Duration	$522.84	$367.31	$562.34	$19.21
(3) Floods Longer Duration	$569.25	$427.15	$607.42	$21.89
(4) Floods Shorter Duration	$475.75	$314.63	$521.11	$18.35
(5) Now Floods With Diversion	$607.50	$459.76	$641.09	$27.23
	With Diversion			
(1) Does not flood	$573.47	$416.98	$599.83	$22.72
(2) Floods Same Duration	$522.84	$367.31	$562.34	$19.21
(3) Floods Longer Duration	$564.83	$418.69	$607.42	$21.54
(4) Floods Shorter Duration	$478.59	$316.25	$521.92	$18.34
(5) Now Floods With Diversion	$597.95	$450.96	$641.09	$23.99

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 48. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 500-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	566.68	423.93	604.84	21.72
3	6 to 10	615.65	470.75	654.03	26.33
5	11 to 15	na	na	na	na
5	16 to 20	590.14	443.45	621.95	25.89
5	Over 20	613.99	465.83	648.24	27.73
		With Diversion			
3	1 to 5	562.77	416.50	604.83	21.41
3	6 to 10	602.00	452.34	654.03	24.24
5	11 to 15	na	na	na	na
5	16 to 20	585.52	443.45	621.95	23.88
5	Over 20	602.60	451.91	648.24	24.29

Na=not applicable. There were no storage areas in those hydrology groups.
[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Estimation of Gross Revenues Only in Years When Diversion Creates Losses

Over the range of conditions evaluated in the Monte Carlo simulation, a number of combinations of planting start dates and flood event start dates do not result in revenue losses while a considerable number of situations result in revenue losses. When both outcomes are averaged, the values are useful in framing the magnitude of the potential revenue losses in the staging area from a policy perspective. But those revenue estimates do not accurately portray the average value when only losses are evaluated. In other words, if the producers have a spring where planting delays actually occur, those potential revenue losses are likely to differ from values that have been combined with years when delays did not occur.

The estimated gross revenues for only the replications where a revenue loss was incurred due to delayed planting associated With the Diversion are presented in Tables 49 through 53. Gross revenues presented in Tables 49 through 53 cannot be compared to gross revenues in the previous section. Observations in the simulation where a revenue loss was produced by the Diversion does not necessarily imply that gross revenues will be lower than the average of all replications. The reason is that the entire simulation includes situations where the Diversion does not create a planting delay ($0 losses due to Diversion), but many of those situations are from late regional planting start dates. Having a late regional planting start date is much more likely to produce lower relative revenues than earlier plant start dates due to the use of the yield decline curves.

Table 49. Gross Revenues Only in Years with Losses, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 10-year Flood Event

		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	500.49	341.78	514.90	14.75
3	6 to 10	na	na	na	na
5	11 to 15	na	na	na	na
5	16 to 20	505.31	343.55	514.90	13.77
5	Over 20	na	na	na	na
		With Diversion			
3	1 to 5	499.17	340.15	514.89	15.07
3	6 to 10	na	na	na	na
5	11 to 15	na	na	na	na
5	16 to 20	499.19	340.63	514.76	15.11
5	Over 20	na	na	na	na

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Table 50. Gross Revenues Only in Years With Losses , Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 25-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	509.68	420.72	538.66	13.46
3	6 to 10	572.55	530.74	602.05	15.83
5	11 to 15	na	na	na	na
5	16 to 20	594.35	557.76	618.81	23.72
5	Over 20	590.11	536.64	619.08	24.76
		With Diversion			
3	1 to 5	502.43	419.40	534.36	13.84
3	6 to 10	553.97	495.34	592.03	14.80
5	11 to 15	na	na	na	na
5	16 to 20	571.39	553.93	600.75	15.34
5	Over 20	558.76	511.27	592.69	15.75

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Table 51. Gross Revenues Only in Years With Losses , Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 50-year Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	540.67	389.38	565.23	17.52
3	6 to 10	585.99	440.78	608.84	17.53
5	11 to 15	644.21	527.11	654.03	12.04
5	16 to 20	623.75	481.21	637.42	14.91
5	Over 20	609.85	468.67	627.17	17.45
		With Diversion			
3	1 to 5	534.92	380.05	564.96	18.63
3	6 to 10	571.99	414.56	608.58	20.88
5	11 to 15	635.84	499.07	653.87	15.05
5	16 to 20	612.13	464.25	637.35	18.00
5	Over 20	591.62	433.58	627.05	20.98

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Table 52. Gross Revenues Only in Years With Losses, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 100-year Flood Event

Hydrology Group	Difference in Total Days	Gross Revenues Per Acre[a] Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	538.21	387.21	566.52	18.22
3	6 to 10	603.78	459.35	633.17	19.86
5	11 to 15	na	na	na	na
5	16 to 20	609.15	464.33	622.42	14.71
5	Over 20	620.03	481.71	638.87	18.42
		With Diversion			
3	1 to 5	532.26	377.31	566.49	19.04
3	6 to 10	586.61	436.33	632.20	22.42
5	11 to 15	na	na	na	na
5	16 to 20	596.77	447.94	622.31	18.01
5	Over 20	601.62	444.67	638.64	21.41

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Table 53. Gross Revenues Only in Years With Losses, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 500-year Flood Event

Hydrology Group	Difference in Total Days	Gross Revenues Per Acre[a] Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	571.90	423.93	604.84	19.72
3	6 to 10	628.53	485.18	654.03	19.02
5	11 to 15	na	na	na	na
5	16 to 20	608.55	462.86	621.95	14.82
5	Over 20	629.00	492.15	648.24	18.73
		With Diversion			
3	1 to 5	566.67	416.50	604.83	20.46
3	6 to 10	605.70	452.34	652.89	23.74
5	11 to 15	na	na	na	na
5	16 to 20	597.26	448.43	621.88	17.76
5	Over 20	609.94	451.91	648.02	21.84

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Estimation of Potential Revenue Losses by Crop

As was discussed in the Converting Planting Delays into Potential Revenue Losses section, average revenues for storage areas can include situations where some crops experience a planting delay while other crops may not be delayed. This is most likely to occur when corn, wheat, or sugarbeets have planting delays but soybeans are not delayed. Identifying potential revenue losses by crop would be useful for producers. Data were not collected to identify the composition of land ownership Within the staging area (or Within individual storage areas). Information on how acreage Within each storage area was distributed among producers also was not collected. Most storage areas are not likely farmed by one producer, and therefore for any year during a major flood event, one producer may intend to plant a different crop on his share of the storage area than the crop another producer may intend to plant. The potential revenue losses between those two producers in a flood event could be considerably different than the average revenue values (and losses) reported for the entire storage area.

Soybeans have the lowest frequency of revenue loss among the four crops (the frequency of per-acre losses for all crops is presented in Appendix G). Soybeans also have the lowest relative yield decline of the four crops. In other words, over the planting periods evaluated in this study, planting delays have less relative impact on soybeans than corn, wheat, or sugarbeets. Soybeans also are planted later in the spring, reducing the likelihood of planting delays due to the use of the staging area. Those factors contribute to soybeans having the lowest per-acre revenue losses. Soybeans also comprise the largest share of crops grown in the staging area, which further acts to reduce the average revenue loss when all crops are combined Within an entire storage area.

Sugarbeets clearly have the largest average per-acre revenue losses of the four crops (Table 54). However, those losses occur on relatively few acres. The small percentage of acres planted to sugarbeets Within the staging area acts to limit the influence of revenues losses when all crops are included in average losses for a storage area. Averaged across all 10,000 replications, the revenue losses per acre for sugarbeets varied from a few dollars in a 10-year event to $47 per acre in a 500-year event (Table 54).

Average per acre revenue losses for wheat generally exceeded the per acre losses for corn (Table 54). While corn has a larger overall gross revenue per acre, the relative price per bushel ($4.35 for corn versus $6.87 for wheat) and the difference in the relative rate of yield decline in the first week after optimal planting has ended suggest greater revenue losses for wheat. Of lesser importance, the last day of optimal planting for wheat was one day earlier than corn, providing a slightly longer period of non-optimal planting than corn since prevent plant and switch dates were modeled to be the same for each crop.

The average of a revenue loss (i.e., only losses were averaged) was estimated for each crop (Table 55). As would be expected, those estimates followed the overall pattern found in Table 54. If a loss was incurred due to planting delays, sugarbeets clearly had the largest per revenue decline, followed by wheat, corn, and soybeans. The distinction between the values in Tables 54 and Table 55 is important because not all flood situations will result in losses (Table 54); but if losses were to occur (Table 55), it is helpful to understand how the effects of averaging no losses influence the overall values.

Prices will play an important role the amount of revenue loss. With wheat yield declining about 1 bushel per day after the optimal planting window has ended, revenue losses will be proportional With respect to price changes. Similar observations can be made for the other crops, because yield losses due to planting delays were modeled to be linear for soybeans and sugarbeets; however, price changes will result in proportional changes in revenues. The yield decline for corn was not linear; however, price changes will have similar effects on the revenue losses for corn as the other crops, especially in situations when delays result in planting near the end of the non-optimal period as that is when the largest yield declines for corn are observed.

Table 54. Revenue Loss Averaged Over Entire Monte Carlo Simulation, by Crop, between With and Without Diversion

Crop and Hydrology Group		Potential Revenue Losses Per Acre[a]				
		10-Year	25-Year	50-Year	100-Year	500-Year
	Difference in Total Days[b]	---------------------------- average of 10,000 replications ----------------------------				
Corn						
3	1 to 5	-$0.75	-$5.04	-$5.86	-$7.44	-$5.07
3	6 to 10	na	-$8.46	-$9.50	-$14.46	-$15.05
5	11 to 15	na	na	-$1.38	na	na
5	16 to 20	-$2.99	-$9.59	-$4.78	-$5.49	-$11.71
5	Over 20	na	-$6.80	-$11.24	-$11.72	-$9.16
Soybeans						
3	1 to 5	$0	-$0.02	-$0.02	-$0.07	-$0.03
3	6 to 10	na	-$0.01	-$0.01	-$0.06	-$0.04
5	11 to 15	na	na	$0.00	na	na
5	16 to 20	$0	$0.00	$0.00	$0.00	-$0.01
5	Over 20	na	-$0.01	-$0.01	-$0.01	-$0.02
Wheat						
3	1 to 5	-$1.35	-$7.90	-$8.86	-$9.04	-$7.57
3	6 to 10	na	-$13.56	-$15.18	-$21.58	-$22.55
5	11 to 15	na	na	-$2.96	na	na
5	16 to 20	-$5.89	-$16.94	-$8.87	-$9.90	-$19.97
5	Over 20	na	-$11.60	-$19.22	-$19.83	-$14.82
Sugarbeets						
3	1 to 5	-$2.61	-$15.62	-$18.49	-$17.00	-$16.52
3	6 to 10	na	-$28.65	-$32.72	-$45.40	-$47.40
5	11 to 15	na	na	-$6.35	na	na
5	16 to 20	-$11.49	-$35.97	-$19.22	-$21.36	-$42.24
5	Over 20	na	-$24.40	-$40.54	-$41.80	-$31.38

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology groups and includes replications With no revenue loss.

[b] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

Table 55. Average Value of a Revenue Loss, by Crop, between With and Without Diversion, (excludes replications With zero losses)

Crop and Hydrology Group		Potential Revenue Losses Per Acre[a]				
		10-Year	25-Year	50-Year	100-Year	500-Year
	Difference in Total Days[b]	--------------------------- average of a revenue loss ---------------------------				
Corn						
3	1 to 5	-$2.31	-$7.95	-$8.72	-10.04	-$6.83
3	6 to 10		-$14.21	-$16.99	-20.41	-$25.28
5	11 to 15			-$7.56		
5	16 to 20	-$10.41	-$18.34	-$11.84	-13.60	-$19.67
5	Over 20		-$12.86	-$20.09	-19.68	-$15.69
Soybeans						
3	1 to 5	-$0.40	-$0.60	-$0.56	-0.89	-$0.40
3	6 to 10		-$0.57	-$1.18	-1.12	-$2.18
5	11 to 15			-$0.60		
5	16 to 20	-$0.77	-$0.58	-$0.71	-0.82	-$0.60
5	Over 20		-$0.59	-$0.71	-0.64	-$0.71
Wheat						
3	1 to 5	-$4.12	-$12.45	-$13.19	-12.19	-$10.21
3	6 to 10		-$22.77	-$27.08	-30.43	-$37.86
5	11 to 15			-$15.83		
5	16 to 20	-$20.22	-$32.29	-$21.85	-24.37	-$33.52
5	Over 20		-$21.89	-$34.30	-33.29	-$25.33
Sugarbeets						
3	1 to 5	-$7.95	-$24.62	-$27.52	-22.93	-$22.28
3	6 to 10		-$48.09	-$58.42	-64.05	-$79.56
5	11 to 15			-$33.89		
5	16 to 20	-$39.46	-$68.62	-$47.28	-52.55	-$70.89
5	Over 20		-$46.02	-$72.39	-70.16	-$53.64

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology groups and excludes replications With no revenue loss.

[b] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

Distribution of Revenue Losses

Revenue losses for all crops for all storage areas were summed, and sorted from lowest to highest over the 10,000 replications. The distribution of the revenue losses for storage areas in Hydrology Group 3 were compared among the five flood events (Figure 42). Across all flood events, except the 10-year flood event, Hydrology Group 3 is indicative of a relative high frequency of modest overall revenue losses. By comparison, overall revenue losses for storage areas in Hydrology Group 5 are slightly less frequent, but of greater magnitude (Figure 43). Overall revenue losses were higher in the 100-year event than in the 500-year event in both Hydrology Groups 3 and 5. The importance of the difference in revenue losses is that a 100-year flood event is likely to occur five times more frequently than a 500-year flood event (1% annual chance for a 100-year flood event versus 0.2% annual chance for a 500-year flood event).

Figures 42 through 44 show that in all flood event sizes, a number of spring planting conditions result in very low to no total revenue losses in the staging area. Revenue losses are not necessarily going to occur in every flood event. Contrasting that situation, a majority of the conditions evaluated did produce revenue losses for producers.

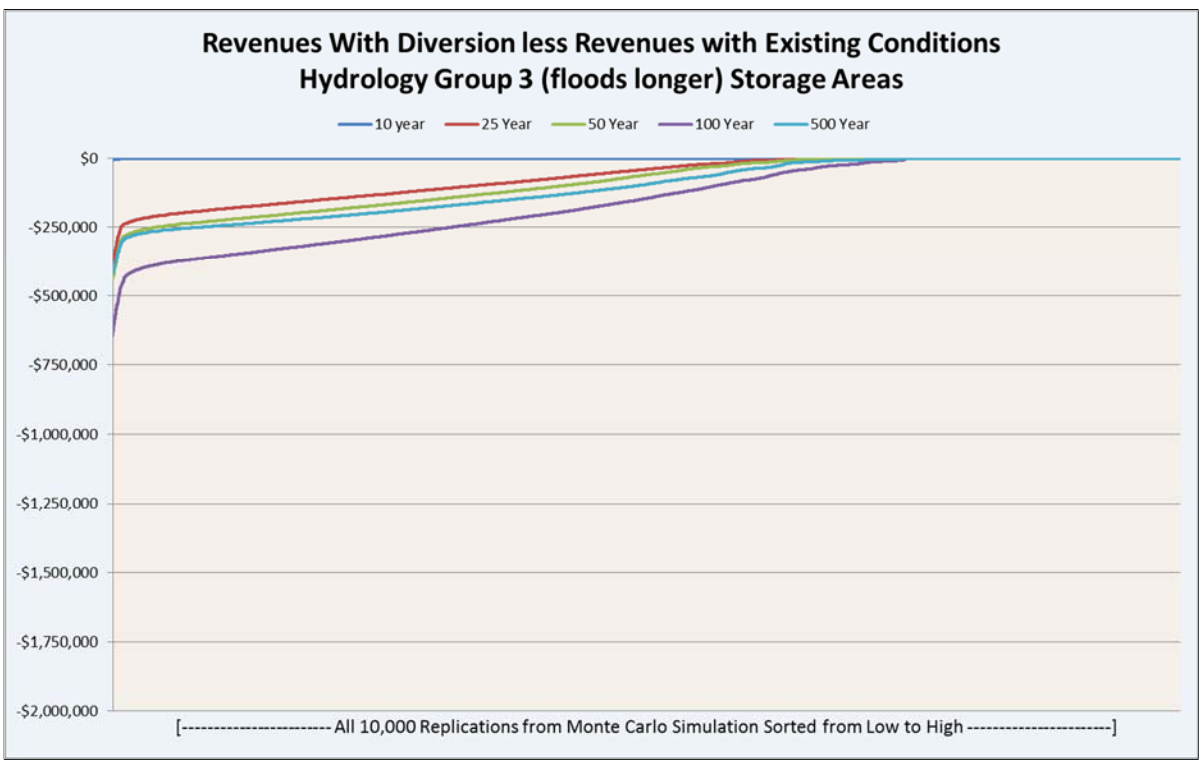

Figure 42. Sorted Distribution of Total Revenue Losses, Hydrology Group Three, All Flood Event Sizes, for All Monte Carlo Replications.

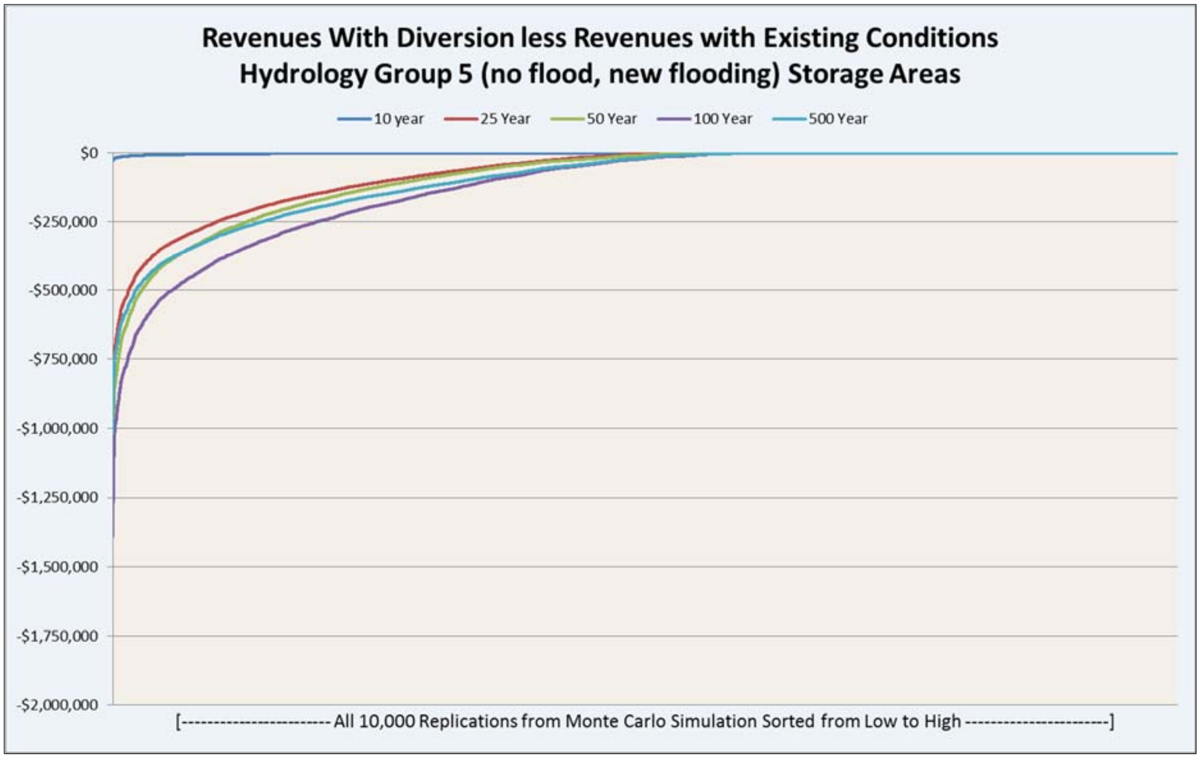

Figure 43. Sorted Distribution of Total Revenue Losses, Hydrology Group Five, All Flood Event Sizes, for All Monte Carlo Replications.

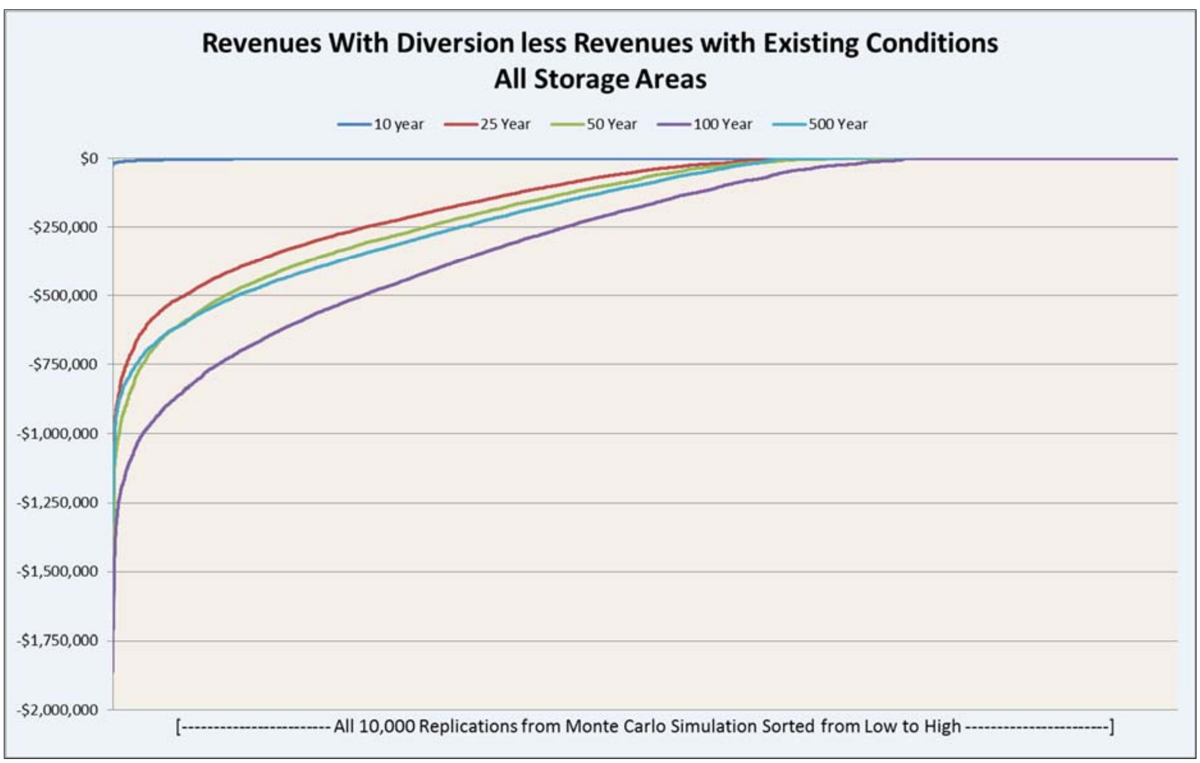

Figure 44. Sorted Distribution of Total Revenue Losses, All Hydrology Groups, All Flood Event Sizes, for All Monte Carlo Replications.

Sensitivity of Results to Key Parameters

Numerous factors will contribute to future potential revenue losses for producers Within the staging area. Key economic factors, such as future prices, yields, and crop mix are obvious. Other factors, largely related to weather, include timing of the flood event, duration of the flood event, timing of regional planting, and pace of planting. The study recognizes that all these factors will influence revenue losses associated With delayed planting Within the staging area, even though sensitivity analysis was not conducted on those factors.

Another set of factors relate to hydrology and the ability to accurately predict the duration of water inundation. Duration of water inundation is critical, not because it is perceived to influence dry-down periods, but because those estimates are based on simulated analyses. The Diversion has not been built, so it remains unproven if water will accumulate and dissipate as planned. However, even if the hydrology modeling proves to be quite accurate, the duration of spring flood events is highly variable. To better gauge how sensitive planting delays might be to a change in the time from staging activation to when the effects of flooding would be gone, the dry-down period was decreased from 10 days to 6 days and increased from 10 to 14 days. Essentially, the adjustment adds and subtracts four days to the dates when the effects of flooding are over.

For lands that are inundated Without the Diversion (Hydrology Groups 2, 3, and 4), any adjustment in the dry-down period will have equal effects in both the Without and With Diversion conditions. If the dry-down period is extended for those hydrology groups, the degree of revenue loss from planting delays may increase, but those effects would not be the result of the Diversion. However, Hydrology Group 5 is directly affected by the dry-down period. In the absence of the Diversion, those storage areas would not flood and therefore would not have a dry-down period.

Hydrology Group 5 storage areas were evaluated for the 25-year event (Table 56). A 4-day decrease in the dry-down period resulted in situations With no planting delays increasing from 51 percent of the 10,000 replications to 67 percent. Conversely, adding 4 days to the dry-down period resulted in the number of situations With no planting delays going from 51 percent to 37 percent.

Table 56. Change in Days of Planting Delay With Adjustments to Dry-down Period, Hydrology Group Five, 25-year Flood Event

Days of Planting Delay	Dry-down Period		
	6-day	10-day	14-day
	----------- share of 10,000 replications ------------		
0 (no delay)	66.8%	51.1%	36.5%
1	3.7%	4.0%	3.8%
2 to 5	13.4%	15.3%	14.8%
6 to 10	11.1%	16.2%	18.9%
11 to 15	4.1%	9.4%	15.3%
16 to 20	0.9%	3.4%	7.8%
20+	0.04%	0.5%	2.9%

Evaluation of 1997-type Flood Event

The 1997 flood event is characterized by high flow rates in Fargo which occurred for longer periods than other large flood events (see Table 1). Since the duration of water storage is a key factor affecting potential planting delays, the 1997 flood event would provide an important contrast to the simulated flood events (i.e., the five flood events used throughout this study) because of the duration of water flows. A flood event representing the 1997 flood was provided using the HEC-RAS version 7.2 modeling.

Probability of Losses During a Flood Event

About 14,600 acres would be inundated longer With the Diversion in a 1997-type flood event. Those storage areas (Hydrology Group 3) could expect a 90 percent annual chance of experiencing revenue losses based on planting delays due to the Diversion (Table 57). Similarly, about 13,000 acres would flood With the Diversion that would not flood With existing conditions. Hydrology Group 5 storage areas have a 78 percent annual chance of incurring revenue losses based on planting delays due to the Diversion.

Despite a high likelihood of incurring revenue losses in a 1997-like flood event, Hydrology Group 3 revenue losses due to the Diversion were expected to be $25 or less per acre for storage areas With 1 to 7 additional days of delay (Table 58). For Hydrology Group 3 storage areas With 8 to 15 additional days of delay, a 1997-type flood event produced revenues losses of $25 per acre or less in 64 percent of the replications, and produce revenue losses ranging from $26 to $50 per acre in 25 percent of the replications (Table 58). Hydrology Group 5 storage areas that have a difference of 25 or more days due to the Diversion have a 14 percent annual chance of incurring revenue losses ranging from $26 to $50 per acre, and a 12 percent annual chance of incurring revenue losses ranging from $51 to $75 per acre (Table 58).

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Table 57. Probability of Losses Resulting from Use of the Staging Area, by Hydrology Group, 1997-type Flood Event

Hydrology Groups	No Loss	$0 to $25/acre[a] Loss	$26 to $50/acre[a] Loss	$51 to $75/acre[a] Loss	$76 to $100/acre[a] Loss	Positive Impact per Acre	Any Loss	Acres
	------------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------------							
(1) Does not flood	100%	0%	0%	0%	0%	0%	0%	9,960
(2) Floods Same Duration	100%	0%	0%	0%	0%	0%	0%	2,277
(3) Floods Longer Duration	8.5%	91.5%	0%	0%	0%	0%	91.5%	14,551
(4) Floods Shorter Duration	3.1%	0%	0%	0%	0%	96.9%	0%	4,529
(5) Now Floods With Diversion	22.3%	51.7%	21.1%	4.5%	0.4%	0%	77.7%	12,968

[a] The range of losses per acre represent an average of all storage areas With the hydrology group.

Table 58. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 1997-type Flood Event

	Time from Activation of Staging Area until Effects of Flooding are over[a]									
Hydrology Group	Without Diversion	With Diversion	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	Any Loss	Acres[c]
	-------------------- days --------------------			------------------------- Based on 10,000 replications from Monte Carlo Simulation -------------------------						
3	29.6	32.4	1 to 7	8.5%	91.5%	0.0%	0.0%	0.0%	91.5%	12,254
3	18.1	28.8	8 to 15	13.0%	62.5%	24.5%	0.0%	0.0%	87.0%	2,935
5	na	na	16 to 20	na	na	na	na	na	na	na
5	0	22.9	21 to 25	43.8%	39.4%	13.9%	2.5%	0.3%	56.2%	6,767
5	0	28.4	Over 25	22.3%	36.6%	27.9%	12.0%	1.1%	77.7%	5,563

Na=not applicable. There were no storage areas in those categories.

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

[c] Acreage in Hydrology Groups 3 and 5, delineated by days of delay, will not match the acreage in the Hydrology Groups 3 and 5 found in Table 57 due to one storage area moving from Group 5 in the standard grouping to Group 3 in the days of delay groupings.

Gross Revenues per Acre With and Without Diversion

The gross revenues per acre were averaged over all 10,000 replications for the five hydrology groups for the 1997-like flood event. In addition to average revenues, the minimum and maximum observed gross revenues were included to provide some perspective on the potential range of observed revenues for the different hydrology groups. The gross revenues are subject to the price and target yield assumptions, and the yield decline functions used in the model.

Storage areas that would not flood in a 1997-like event averaged $599 per acre, which represents all of the combinations of early and late spring planting conditions but does not include any effects from either natural flooding or Diversion-related flooding (Table 59). The average gross revenue among Hydrology Groups 2, 3, and 4 is not equal because the duration of water inundation (natural flooding) varies among the groups (see Appendix C).

The difference in gross revenues between With and Without Diversion for the hydrology groups affected by flooding ranges from around $6 per acre With storage areas that would require 1 to 7 additional days for the effects of flooding to be over With the Diversion to $22.50 per acre for storage areas that require over 25 additional days for the effects of flooding to be over With the Diversion (Table 60).

Table 59. Gross Revenues, by Hydrology Group, With and Without Diversion, 1997-type Flood Event				
	Gross Revenues Per Acre[a]			
Hydrology Group	Mean[b]	Minimum	Maximum	Standard Deviation
	With Existing Conditions (Without Diversion)			
(1) Does not flood	599.27	449.04	630.99	26.01
(2) Floods Same Duration	496.02	342.59	547.44	20.73
(3) Floods Longer Duration	540.56	388.86	586.01	19.80
(4) Floods Shorter Duration	463.18	305.68	510.19	18.68
(5) Now Floods With Diversion	597.71	450.08	630.13	26.38
	With Diversion			
(1) Does not flood	599.27	449.04	630.99	26.01
(2) Floods Same Duration	496.02	342.59	547.44	20.73
(3) Floods Longer Duration	531.74	376.75	585.12	19.85
(4) Floods Shorter Duration	465.63	305.68	511.65	18.21
(5) Now Floods With Diversion	582.26	437.32	630.06	22.33

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Table 60. Gross Revenues, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 1997-type Flood Event					
		Gross Revenues Per Acre[a]			
Hydrology Group	Difference in Total Days	Mean[b]	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 7	539.82	387.02	587.25	19.95
3	8 to 15	560.73	418.91	595.63	21.76
5	16 to 20	na	na	na	na
5	21 to 25	601.24	453.17	633.94	26.62
5	Over 25	590.96	443.96	622.75	25.89
		With Diversion			
3	1 to 7	533.08	379.09	586.37	19.83
3	8 to 15	544.79	393.47	594.87	19.49
5	16 to 20	na	na	na	na
5	21 to 25	590.33	440.38	633.94	23.44
5	Over 25	568.39	415.21	622.59	22.05

Na=not applicable. There were no storage areas in those hydrology groups.
[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.
[b] Average of all 10,000 replications.

Estimation of Gross Revenues Only in Years When Diversion Creates Losses

Over the range of conditions evaluated in the Monte Carlo simulation, a relatively few combinations of planting start dates and flood event start dates did not result in revenue losses while considerable number of situations did result in revenue losses. When both outcomes are averaged, the values are useful in framing the magnitude of the potential revenue losses in the staging area from a policy perspective. The estimated gross revenues for only the replications where a revenue loss was incurred due to delayed planting are presented in Tables 65 through 66. Due to the relatively high number of replications With some planting delays resulting in revenue losses, the gross revenues when a loss was observed are similar to the gross revenues for the entire simulation (i.e., when non-loss observations are included in the averages).

Table 61. Gross Revenues Only in Years With Losses, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, 1997-type Flood Event

Hydrology Group	Difference in Total Days	Gross Revenues Per Acre[a] Mean	Minimum	Maximum	Standard Deviation
		With Existing Conditions (Without Diversion)			
3	1 to 5	540.66	387.02	587.25	19.98
3	6 to 10	564.15	418.91	595.63	20.15
5	11 to 15	na	na	na	na
5	16 to 20	616.51	477.57	633.94	17.52
5	Over 20	598.85	444.44	622.75	21.63
		With Diversion			
3	1 to 5	533.30	379.09	586.37	20.04
3	6 to 10	545.83	393.47	594.87	19.49
5	11 to 15	na	na	na	na
5	16 to 20	597.10	440.38	633.76	21.25
5	Over 20	569.80	415.21	622.59	22.39

Na=not applicable. There were no storage areas in those hydrology groups.

[a] Represents an average of all storage areas Within the hydrology group. Revenues represent potential income based on planting conditions. Effects of crop growing conditions throughout the remainder of the season were not included.

Distribution of Gross Revenues

Revenue losses for all crops for all storage areas were summed, and distributed over the 10,000 replications for the 1997-like flood event. The distribution of the revenue losses for storage areas in Hydrology Group 3 were compared between the two events (Figure 45). In the 1997-like flood event, Hydrology Group 3 is indicative of a relative high frequency of modest overall revenue losses. By comparison, overall revenue losses for storage areas in Hydrology Group 5 are slightly less frequent, but of greater magnitude (Figure 46).

Figures 45 through 46 show that even in a 1997-like flood event, about 25 percent of the spring planting conditions result in very low to no total revenue losses in the staging area. Contrasting that situation, in 75 percent of the conditions, the Diversion resulted in revenue losses for producers. The comparison of the distribution of the 1997-like event was similar in magnitude to the revenues losses observed in the 500-year event but less than the damages observed in the 100-year flood event. These results are consistent With the 1997-flood event being designated as a 50-year flood event. The big difference between the 1997-type flood event, being a 50-year flood event, and the 500-year flood event is that a 1997-like flood event is 10 times more likely to occur.

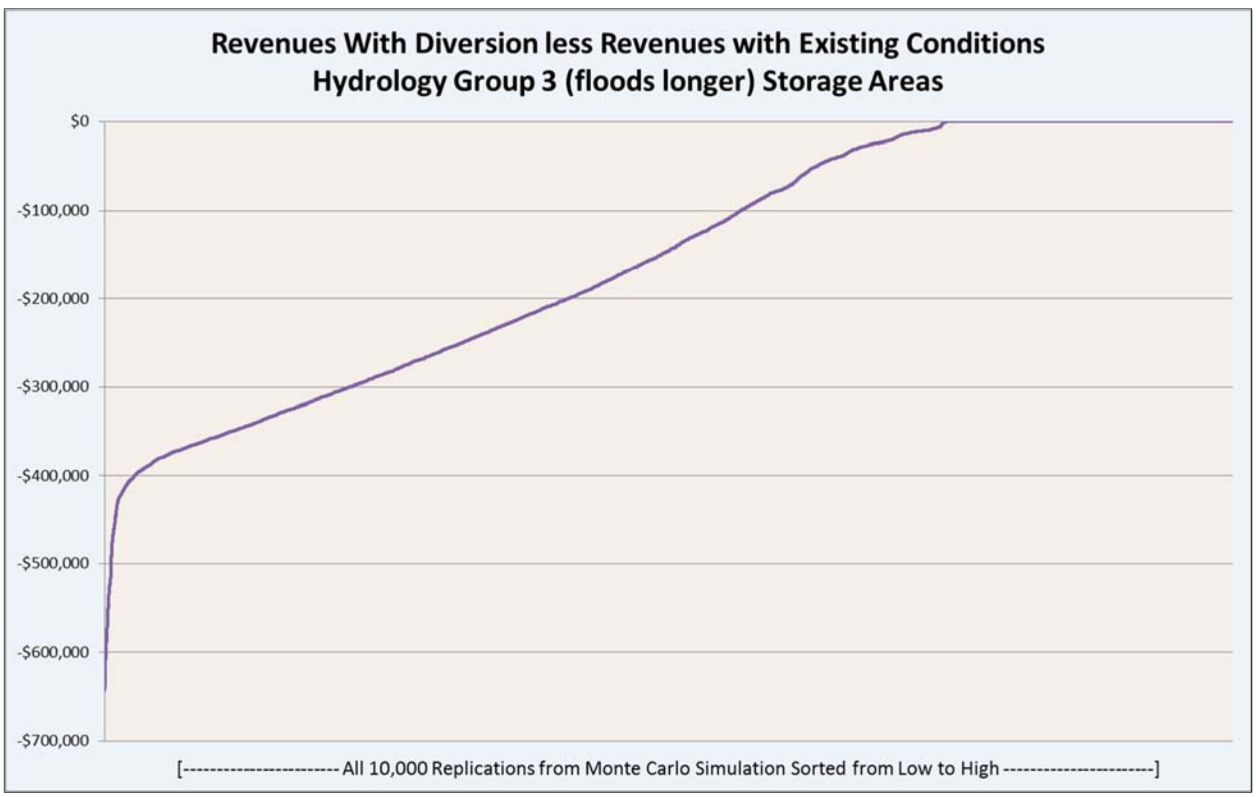

Figure 45. Sorted Distribution of Total Revenue Losses, Hydrology Group Three, 1997-like Flood Event, for All Monte Carlo Replications

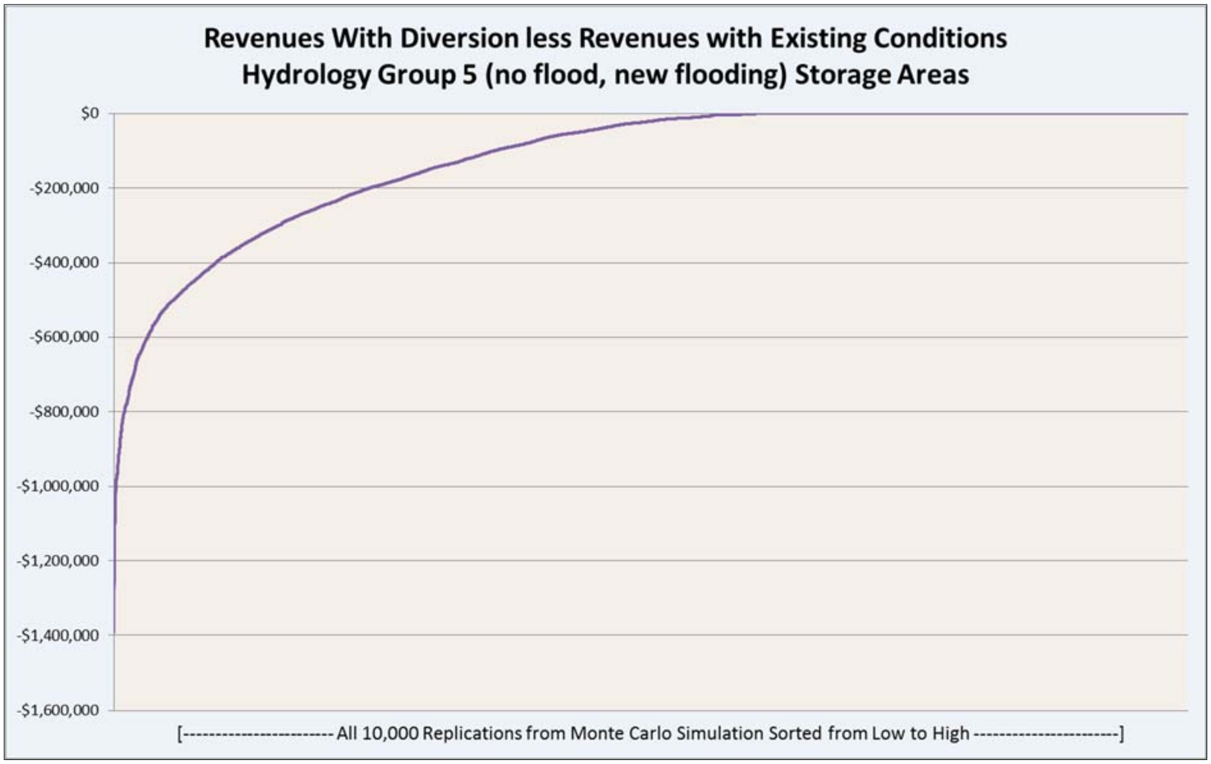

Figure 46. Sorted Distribution of Total Revenue Losses, Hydrology Group Five, 1997-like Flood Event, for All Monte Carlo Replications

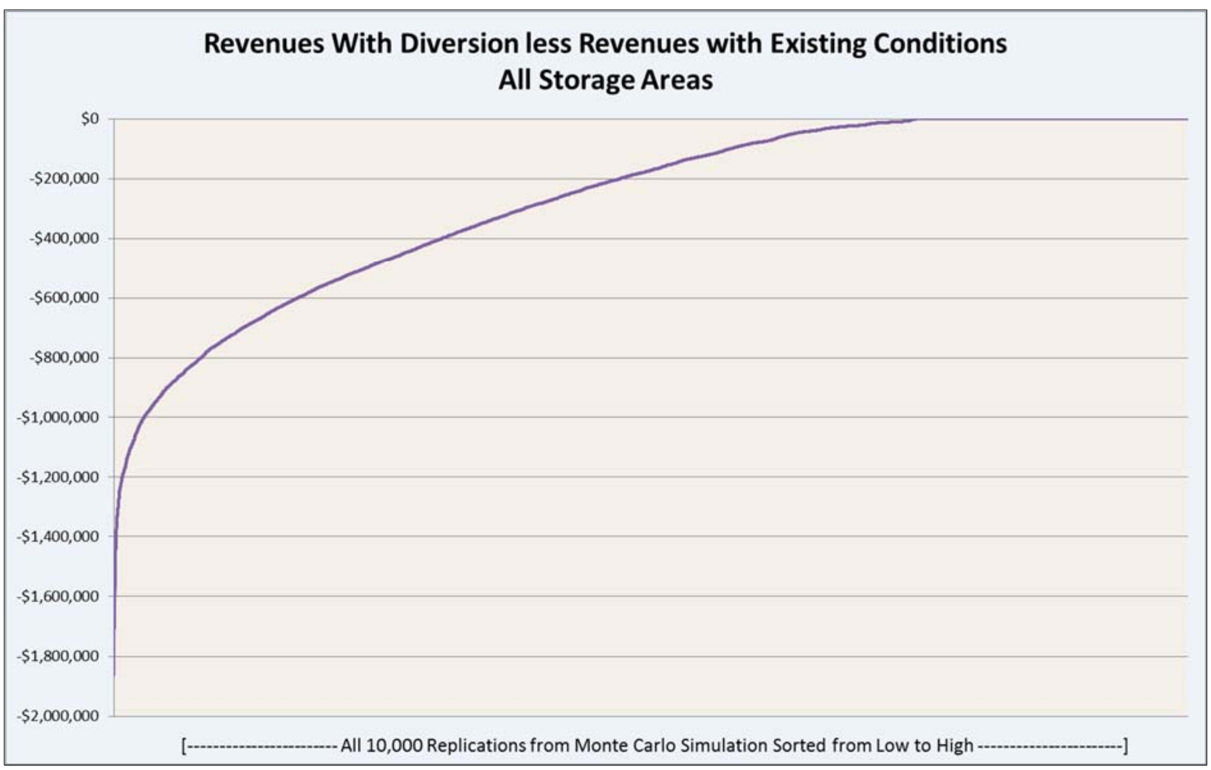

Figure 47. Sorted Distribution of Total Revenue Losses, All Hydrology Groups, 1997-like Flood Event, for All Monte Carlo Replications

Loss of Insurance Payments

Destruction of a crop by a man-made event is not covered by Federal crop insurance. The Diversion Authority commissioned a study by Watts and Associates to evaluate the eligibility concerns and other issues pertaining to federal crop insurance[12]. As discussed throughout this analysis, storage areas that now flood for longer duration (Group 3) and those storage areas that would flood With use of the staging area that would not otherwise flood (Group 5) will experience the greatest adverse impact of operating the proposed Diversion. Those storage areas, comprising a substantial acreage Within the staging area for most large flood events, will likely be ineligible for crop insurance to cover losses due to delayed planting.

Several general questions will need to be addressed to fully understand the implications of the staging area on federal crop insurance.

1) Will storage areas that normally flood but are not adversely affected by use of the staging area remain eligible for federal crop insurance when the staging area is activated? If those storage areas lose eligibility for federal crop insurance to compensate for delayed planting, the operation of the Diversion may generate liabilities associated With delayed planting even though the use of the staging area did not add to the planting delays that would have occurred With existing (no Diversion) conditions.

2) Would operation of the Diversion be responsible for the total revenue loss due to delayed planting on lands that would otherwise flood but now flood longer (Group 3)? Alternatively, does extending the period of inundation nullify the eligibility of federal crop insurance to compensate for the portion of delayed planting associated With natural inundation? If so, the potential liabilities associated With storage areas in Group 3 would include the compensation that would have accrued to the producer through federal crop insurance for delayed planting associated With natural inundation. In other words, the damages to the producer would include the portion of loss covered by federal crop insurance and 100 percent of the loss attributable to the additional delays created by the staging area.

3) How would the loss of eligibility for federal crop insurance during a spring flood affect the producer in years Without spring flood events? Will federal crop insurance use yields in a flood year in the estimation of the producer's actual production history (APH) if a producer was ineligible for federal crop insurance that spring? While one year in seven can currently be removed from a producer's APH, potential losses could occur if a producer cannot drop a poor yield due to a flood year (e.g., producer already has a low yield from a previous year due to a flood or from other causes) in the calculation of his APH. The implication of lowering a producer's APH is that compensation levels are lowered, and therefore indemnities from federal crop insurance for all other perils could be reduced due to the lower compensation levels.

Previous meetings by the FM Diversion Authority and the Ag Policy Sub-committee have begun discussions that suggest the Diversion Authority consider an insurance program similar to federal crop insurance to compensate losses incurred by agricultural producers due to the Diversion. But as was also mentioned in those discussions, traditional crop insurance does not fully compensate producers for a financial loss. Accordingly, any compensation program based solely on the provisions associated With

[12] See discussion of crop insurance as it pertains to the proposed Diversion at http://www.fmDiversion.com/pdf/APS%20Minutes/2012/AUG1412M.pdf.

traditional crop insurance must provide additional compensation beyond that provided by ordinary crop insurance policies to fully compensate producers.

Goals for considering crop insurance include 1) compensating the producer, rather than the landowner, 2) reducing the initial cost of compensating for use of the agricultural land in the staging area, and 3) placing the risk of crop damage due to the Diversion on the Diversion Authority, rather than on the landowners and farm operators.

Since traditional insurance works by having producers pay a premium to insure a degree of risk related to lost income, creating similar provisions that would require existing producers to pay premiums to offset man-made losses would be inappropriate. It would place some of the financial responsibility for compensation back on the affected producers and it would be analogous to creating a savings account that would return producer's own money when the staging area is operated.

Crop insurance has many facets, provisions, payment levels, and eligibility conditions that must be addressed. Including crop insurance was initially considered in the beginning stages of this project. However as the details on how to model the various conditions were more clearly identified Within the limitations of the existing model, the range of options for including crop insurance were reduced. The ability to address the insurance issues would be substantially limited in scope. Further, it became apparent that producer level data would greatly assist in making those analyses accurate. Resources were not available to obtain producer-level data. Some elements of how the Diversion may impact the compensation level for producers in years when the Diversion is not used would add levels of complexity to an already complex analysis (e.g., understanding and predicting the likelihood and magnitude of adjustments to a producer's APH that could result from the use of the staging area). Those effects would require modeling all causes of revenue losses, and examining producer revenues in non-flood years.

Traditional crop insurance may not be appropriate to mitigate the risks to producers, and a replacement income policy may need to be developed. The details of crop insurance or replacement farm income are beyond the scope of this study, but are identified here as an area where additional analysis and expertise may be warranted. While the FM Diversion Authority is exploring these policy options, the FM Diversion Authority is not required to develop an income supplement policy.

<u>Historical Value of Crop Insurance Indemnities</u>

The discussion of crop insurance With respect to the FM Diversion often centers on the ability of those programs to offset potential revenue losses to producers. If producers in the staging area lose eligibility for federal crop insurance to offset losses from planting delays regardless of how the staging area may affect their lands, the Diversion Authority may be responsible for all revenue losses associated With planting delays during a flood year, not just the marginal increase created by the staging area.

Gross indemnities[13] from crop insurance comprised about 4 to 5 percent of direct crop revenues in the four study counties when combining cash receipts from crop sales, government farm program payments, and insurance indemnities from 1995 through 2012 (Table 62). However, crop insurance indemnities, as a percentage of crop revenues, varied considerably among years (Appendix H). For example, crop insurance indemnities ranged annually from 0.5% to 20% of crop revenues in Cass

[13] Gross indemnities refer to the total value of indemnities received from crop insurance, and have not been adjusted for the payments made to obtain coverage.

County, North Dakota from 1995 through 2012. In Clay and Wilken Counties in Minnesota and Richland County in North Dakota, crop insurance indemnities were more consistent as a percentage of crop revenues (Appendix H).

Table 62. Cumulative Crop Revenues, Government Payments, and Insurance Indemnities, Cass and Richland Counties, North Dakota, Clay and Wilken Counties, Minnesota, 1995 through 2012

County	Cash Receipts from Marketings	Government Payments[a]	Crop Insurance Indemnities[b]	Average Percentage of Crop Revenues[c] from Insurance
	------------ 000s 2014 $ ------------			
Cass	5,118,840	556,408	342,912	5.70
Richland	4,492,752	644,017	232,666	4.33
Clay	3,251,747	300,160	135,065	3.66
Wilkin	2,276,847	182,378	96,693	3.78
Total	15,140,185	1,682,963	807,336	4.58

[a] Includes payments for conservation programs, federal disaster aid, and federal farm programs.
[b] Gross indemnities not adjusted for premiums paid.
[c] Crop revenues defined as the sum of cash receipts, government payments, and insurance indemnities.
Sources: Bureau of Economic Analysis (2014).

Adjusted for inflation, insurance indemnities have been increasing since 1989 in the four-county study region (Table 63). Insurance indemnities are larger, on average, in flood years than average indemnities in non-flood years. However if the flood year 2011 is omitted from the averages, average indemnities in flood years and non-flood years are nearly identical (Table 63). Insurance indemnities in the flood year 1997 are considerably lower than the average values in non-flood years.

Table 63. Total Insurance Indemnities, All Causes of Loss, Cass and Richland Counties, North Dakota, Clay and Wilken Counties, Minnesota, 1989 through 2014

Year	Spring Flood Event[a]	Total Indemnities	Year	Spring Flood Event[a]	Ranking of Total Indemnities
		------ 2014 $ ------			------ 2014 $ ------
1989	Yes	17,354,951	1996		5,135,476
1990		5,913,086	1991		5,826,459
1991		5,826,459	1990		5,913,086
1992		6,441,304	1992		6,441,304
1993		38,332,805	2006	Yes	13,538,540
1994		14,016,152	1994		14,016,152
1995		17,789,106	1997	Yes	15,929,064
1996		5,135,476	2012		16,332,364
1997	Yes	15,929,064	1989	Yes	17,354,951
1998		29,591,664	1995		17,789,106
1999		36,831,605	2003		18,202,257
2000		31,101,145	2002		19,121,434
2001	Yes	33,395,047	1998		29,591,664
2002		19,121,434	2000		31,101,145
2003		18,202,257	2001	Yes	33,395,047
2004		55,241,401	2005		35,907,309
2005		35,907,309	1999		36,831,605
2006	Yes	13,538,540	1993		38,332,805
2007		72,697,001	2010	Yes	39,146,282
2008		94,502,591	2004		55,241,401
2009	Yes	91,508,164	2007		72,697,001
2010	Yes	39,146,282	2013		81,056,589
2011	Yes	194,617,370	2009	Yes	91,508,164
2012		16,332,364	2014		91,958,428
2013		81,056,589	2008		94,502,591
2014		91,958,428	2011	Yes	194,617,370
Averages					
1989-2014		41,595,677			
2000-2014		59,221,728			
2010-2014		84,622,207			
Flood years		57,927,060			
Non-flood years		35,578,851			
Flood years Without 2011		35,145,341	(excluding 2011)		

[a]Flood events exceeding 17,000 cfs in Fargo, North Dakota.
Source: EWG (2015).

Federal crop insurance covers revenue losses from a multitude of causes (Table 64). Despite a host of causes for revenue loss, from 1989 through 2014, over 64 percent of all indemnities were due to excess moisture or precipitation. Excess moisture is a predominate factor in nearly all years from 1989 through 2014 (Table 65).

Table 64. Total Insurance Indemnities, Ranked by Cause of Loss, Cass and Richland Counties, North Dakota, Clay and Wilken Counties, Minnesota, 1989 through 2014

Cause of Loss	Indemnities (2014 $)	Share of Total Indemnities
Earthquake	798	0.00%
Hurricane/Tropical Depression	13,361	0.00%
Fire	17,290	0.00%
Failure of Irrigation Supply	19,124	0.00%
Poor Drainage	21,420	0.00%
Unnamed causes	22,681	0.00%
Tornado	23,718	0.00%
Cyclone	39,726	0.00%
Other causes	179,254	0.02%
Mycotoxin (Aflatoxin)	273,469	0.03%
Cold Winter	384,655	0.04%
Wildlife	396,839	0.04%
Hot Wind	417,361	0.04%
Area Plan Crops Only	1,090,096	0.10%
Insects	1,841,233	0.17%
Other (Snow-Lightning-Etc.)	2,230,337	0.21%
Wind/Excess Wind	5,698,029	0.53%
Flood	7,182,223	0.66%
Heat	8,983,808	0.83%
Frost	15,687,939	1.45%
Freeze	16,316,024	1.51%
Plant Disease	42,529,970	3.93%
Cold Wet Weather	49,654,396	4.59%
Decline in Price	59,333,966	5.49%
Drought	79,203,644	7.32%
Hail	92,463,956	8.55%
Excess Moisture/Precipitation/Rain	697,462,276	64.49%
All Indemnities	1,081,487,595	

Source: EWG (2015).

Table 65. Causes of Loss, by Year, Cass and Richland Counties, North Dakota, Clay and Wilken Counties, Minnesota, 1989 through 2014

Year	Cold Wet Weather	Decline in Price	Drought	Excess Moisture Precip/Rain	Flood	Hail	Heat	Freeze	Frost	Plant Disease	Wind / Excess Wind	All Other
	---------- percentage of loss by year ----------											
1989	0.0	0.0	65.4	1.3	0.0	2.8	24.2	0.2	3.1	0.0	1.9	1.0
1990	0.1	0.0	65.0	5.7	0.0	15.1	1.2	1.5	2.3	1.1	2.1	5.9
1991	0.0	0.0	9.7	40.0	0.0	3.1	1.2	0.0	0.0	37.7	2.1	6.1
1992	7.7	0.0	0.7	19.1	0.1	35.4	0.2	11.7	15.7	0.1	8.2	1.3
1993	6.5	0.0	0.0	74.9	10.1	0.3	0.0	1.6	2.1	4.2	0.0	0.2
1994	0.2	0.0	2.6	70.8	0.9	12.9	0.0	0.0	0.0	11.0	0.8	0.9
1995	0.6	0.0	0.7	86.9	0.7	2.9	2.1	0.2	0.4	3.3	0.7	1.6
1996	0.4	0.0	16.2	67.7	0.6	7.4	0.2	0.5	0.0	2.3	2.5	2.2
1997	0.1	0.0	2.0	72.5	0.6	13.4	0.1	0.0	0.0	9.3	0.2	1.9
1998	0.1	0.0	0.9	76.4	0.5	3.8	0.1	0.0	0.0	17.6	0.0	0.5
1999	0.0	0.0	0.7	77.1	0.0	11.2	0.4	0.0	0.1	9.8	0.4	0.3
2000	0.3	0.0	0.8	59.8	1.1	4.1	0.0	0.1	0.0	33.3	0.1	0.3
2001	0.1	0.0	1.3	61.5	0.0	22.3	0.2	0.0	0.0	13.6	0.4	0.6
2002	3.5	0.0	5.3	56.0	0.3	19.2	1.1	1.1	1.0	8.0	3.4	1.1
2003	0.2	0.2	26.3	35.0	0.4	32.9	1.0	0.0	0.1	2.7	0.1	1.1
2004	30.7	2.9	1.6	27.0	0.0	8.6	0.1	7.1	18.3	1.4	1.6	0.8
2005	0.2	0.0	0.1	88.4	0.6	3.4	0.2	0.0	0.1	6.1	0.3	0.6
2006	0.1	0.3	34.4	47.4	0.0	13.3	0.9	0.0	0.2	3.0	0.0	0.4
2007	0.0	0.2	2.9	58.6	0.0	36.3	0.2	0.0	0.1	0.6	0.1	1.0
2008	1.8	27.2	5.6	43.3	0.1	12.1	0.5	8.3	0.2	0.4	0.1	0.5
2009	12.9	0.0	0.2	84.2	0.3	1.0	0.0	0.8	0.1	0.1	0.0	0.4
2010	6.1	0.8	0.1	85.6	0.6	2.9	0.0	0.0	0.4	3.1	0.1	0.3
2011	1.9	0.3	0.4	92.0	0.6	1.4	0.6	0.7	0.1	1.2	0.7	0.2
2012	0.1	0.5	81.7	8.8	0.0	2.9	1.8	0.1	0.1	0.9	2.3	0.8
2013	1.6	14.9	31.6	38.3	0.4	8.4	1.7	0.6	0.2	1.1	0.2	1.1
2014	8.4	20.3	2.0	63.5	0.0	2.5	0.0	0.2	2.0	0.4	0.1	0.5

Source: EWG (2015).

Converting Event-level Estimates into Annualized Values

Predicting the year(s) when a future flood will occur, or estimating the actual frequency of future floods is impossible. Therefore, any potential future flood damages are often measured and defined by their probability of occurring in any given year. The challenge is that any size flood (and associated differences in damages) could occur in any future year.

One of the difficulties in interpreting event-level damages (i.e., what happens when a flood event actually occurs) is addressing those probabilities since any one event could occur in any given year. The process of annualizing future outcomes attempts use the annual probability that an event will happen with the expected financial impacts of that event to place a value of those occurrences on a per-year basis. In the case of an actual flood-event (i.e., event-level damages), describing and estimating the effects are relatively straightforward. Event-level losses were estimated in this study for several hydrology groups over six different-sized flood events, but what does it mean when those flood events will not occur every year, or alternatively, most years will not have a flood?

One of the challenges present in this study is that there are few common denominators which can be used across all the flood events. The hydrology information suggests that the mix of storage areas within the hydrology groups (and therefore the presence or absence of revenue losses) changes based on flood frequency/size. This creates a problem for interpreting potential annualized values. An individual producer may have land that is inundated with a large flood but is not inundated with smaller, more frequent floods—this condition is considerably different from another producer who may experience extended flood inundation with all flood events. To accurately conduct an annualized assessment at the producer-level, annualization would need to be performed at the storage (or more accurately) at the sub-storage level.

The probability of a no-flood spring or a spring flood event is 100 percent every year. Therefore, the sum of all events being annualized will total to 100, and a substantial portion 0of that probability will represent no-flood years (which means $0 losses due to the Diversion).

Annualized values, therefore represent another manner in which the magnitude of expected damages can be framed. However, two reasons exist why annualized values were not produced in this report.

1) Annualized values are only useful when all damages are included. It would be premature to provide annualized estimates in the absence of damages from lost Federal crop insurance.

2) Annualizing damages for the overall staging area should be estimated by summing the annualized estimates for individual storage areas, or more accurately, from sub-storage areas. Complex hydrology results in many storage areas experiencing different flood effects in different sized flood events. Further, the economic losses vary among the storage areas due to the use of county-level data for the four counties in the study region. Providing annualized estimates for each storage area was beyond the scope of this study.

The annualizing of weather-related damages can be demonstrated using hypothetical values for tornado events. In the hypothetical analysis, there are five sizes of tornados based on the Fujita scale, which range from an F1 to an F5 tornado, with an F5 representing the largest size of tornado. Hypothetically, the annual chance of an F1 tornado was 10 percent (a 10-year occurrence level) and the annual chance of experiencing an F5 tornado is 0.2 percent (500-year occurrence). As tornados increase in size (and their destructive power also increases), the annual likelihood of experiencing that storm decreases, but economic damages increase.

As would be the case with spring flood events, the probability of a no-tornado season and experiencing a tornado storm is 100 percent every year. This hypothetical example will ignore the probability of experiencing more than one tornado storm in any given year.

Hypothetical damages ranged from $20 for an F1 event to $100 for an F5 event (in this example the units are not important) (Table 66). Constructing a piece-wise linear function using those values (see Figure 26 on page 57), and conducting a mathematical integration of that function resulted in annualized damages of $11.70. This hypothetical example demonstrates how annualized values become relatively small compared to event-level damages when there is a high annual probability of no damage.

Table 66. Demonstration of Converting Event-level Damages to Annualized Damages, using Hypothetical Tornado Damages

	Size of Tornado Storms using Fujita Scale				
	F1	F2	F3	F4	F5
Hypothetical Annual Chance[a]	10%	4%	2%	1%	0.2%
Hypothetical Damages	$20	$40	$60	$80	$100
			Annualized Damages = $11.70		

[a] Would not include hypothetical probabilities of more than one storm in any calendar year.

Conclusions

Overall, the economic impact on crop production in the 98 storage areas is probably less than expected. In evaluating the historical data and expected differences in flooding created by the Diversion, several reasons underpin this conclusion.

Discussion

Overall, the economic impact on crop production in the 98 storage areas is probably less than expected. In evaluating the historical data and expected differences in flooding created by the Diversion, several reasons underpin this conclusion.

There are no recorded flows on the Red River due to rain that would trigger the use of the Diversion; the Diversion would only be used to protect against springtime rain and snow melt. The Diversion is not expected to create losses after spring planting season.

Spring snow melt and runoff, in most cases, occur early relative to regional planting starts. Examples of these situations include the start of planting as late as May in 2014 and a large flood event in March in 2009. In the case of 2009, the flood event and planting time periods did not overlap. A large, relatively late flood event, such as 1997, is likely to impose the greatest impact on agricultural producers. Even though the 1997 flood event, for example, occurred in mid- to late April, there was no planting prior to that time due to the late snow melt and overall wet conditions. Again, there was limited overlap between the spring runoff and planting.

The engineering data indicate that the combined capacity of the Red River and the Diversion channel, once the community is protected with dikes, will move extensive amounts of water around the community. The exact amount and timing will not be known until the Diversion Operating Manual is finalized by the Corps, but the preliminary indications are that the Red River will handle 17,000 cfs through the community and the Diversion channel will handle an additional 22,000 cfs around the community. However, despite the stated capacities, the timing and flow of flood waters also will be based on the characteristics of the flood-event, and all floods are unique (e.g., compare the 1997 flood event to the 2009 flood event). The combined flow capacity of 39,000 cfs clearly exceeds the largest observed flow in Fargo of 29,800 cfs observed in 2009. Both the stated design capacity of the Diversion and the current hydrology data suggest that water will not be retained in the staging area for extensive periods, and it is highly likely that those lands will be planted in a flood year.

In the more modest flood events (e.g., 25-year and 50-year events), many storage areas are not adversely affected by the Diversion. A substantial portion of the 98 storage areas, most lying in relatively low elevations, would experience flooding Without the Diversion. Current hydrology modeling is suggesting that the majority of lands that would flood Without the Diversion will experience 1 to 7 days of additional time for the effects of flooding to be gone. For those lands, the Diversion may contribute to a delayed planting but is not responsible for all of the delayed planting. Most lands that will experience new flooding With the Diversion would require up to 25 days from the date when the staging area is activated until the effects of flooding are gone. However, not all of those days translate directly into planting delays. For much of that period, general weather conditions, such as temperature and normal dry-down from snow melt, prevent spring planting.

The impacts of planting delays from Diversion operations on corn, wheat, and sugarbeets are likely to be substantially different than soybeans. Soybeans had the lowest frequency and magnitude of revenue loss of the four crops. Soybeans also have the lowest relative yield decline of the four crops when planted beyond the optimal period. Over the planting periods evaluated in this study, planting delays have less relative impact on soybeans than corn, wheat, or sugarbeets. Soybeans also are planted later in the spring, reducing the likelihood of planting delays due to the use of the staging area. This combination of factors is why soybeans have the lowest per-acre revenue losses. Soybeans also comprise the largest share of crops grown in the staging area, which further reduces the average revenue losses when all crop losses are combined within an entire storage area.

This study represents the first attempt to address potential effects of temporary water storage on agricultural production resulting from the use of the Diversion. As a result of this effort, insights were gained on how the flooding effects vary by location and elevation of land, and how the effects also are influenced by the size of flood event. Examining when the effects of flooding are over and when regional planting typically begins, suggests a high likelihood of relatively short planting delays. These conclusions are extremely helpful in advancing the discussion of how agricultural production might be affected, but a number of additional issues remain unquantified. While this project was not able to address all production-related issues, this study, along with its methodology, lays a strong foundation from which additional production questions can be addressed.

Economic Conclusions

Operation of the Diversion creates a high likelihood of modest planting delays and subsequent revenue loss. About 30,000 to 38,000 acres (depending upon flood size) have a 50 percent to 65 percent chance of a revenue loss in a flood year (excluding 10-year events or smaller).

While the probability of a revenue loss is high, the magnitude of losses is generally modest (less $25/acre average for a storage area). The probability of revenue loss ranging from $26 to $75/acre average within a storage area is about 10 percent for flood events larger than a 10-year event.

The value of crop revenue loss per acre ranges from $0 to more than $200 depending the flood event and crop. The average loss within the range, although informative, does not reveal the risk or variability of loss. Observing the loss 5% above the least loss and 5% below the maximum loss reveals the range of possible losses (Appendix I).

Due to the complexity of the hydrology, which varies by storage area for the flood events evaluated, generalized statements about how producers will be individually affected are difficult. Revenue losses across all acres and crops within a storage area and by hydrology group measures the potential cumulative losses in the staging area and identifies general risk. However, care should be exercised that generalities and averages mask substantial differences for individual crops and storage areas. The economic impacts on some agricultural producers are likely to be considerably different than the average values within the hydrology groups.

Per-acre losses and cumulative losses would be larger if Federal crop insurance indemnities were included. Several uncertainties exist with how Federal crop insurance would be administered in the cases where the Diversion adds to existing flooding but the land would have flooded in the absence of the Diversion. Also, in cases where the Diversion is modeled to have no adverse effect, questions remain if the use of the Diversion affects the eligibility of Federal crop insurance to assist in mitigating planting delays on those lands. To what degree Federal crop insurance coverage will be impacted as a result of Diversion operations is unknown. This study only estimated the revenue losses associated delayed planting that was due to operation of the Diversion. Including the potential value of lost insurance on all lands experiencing a planting delay (regardless if the planting delays was due to the Diversion) would increase the losses to producers and perhaps substantially increase estimated losses generated in this study.

Total losses in this study were based on the assumption that if any portion of a storage area was inundated, all land within that storage area was equally affected. Given the lack of available data to refine that assumption, developing estimates using all acreage was the best approach. However, overall losses due to the use of the Diversion would be sensitive to that assumption. Also if the acreage modeled was expanded to include 'cross-section' areas excluded from this study or additional lands beyond the 98 storage areas, overall losses would likely increase. Finally, including the value of lost insurance indeminites would increase total losses.

This study represents the first attempt to address potential effects of temporary water storage on agricultural production resulting from the use of the Diversion. As a result of this effort, insights were gained on how the flooding effects vary by location and elevation of land, and how the effects also are influenced by the size of flood event. Examining when the effects of flooding may be gone and when regional planting typically begins, suggests a high likelihood of relatively short planting delays. These conclusions are extremely helpful in advancing the discussion of how agricultural production might be affected, but a number of additional issues remain unquantified. While this project was not able to address all production-related issues, this study, along with its methodology, lays a strong foundation from which additional production questions can be addressed.

Recommendations

-) **All lands affected by temporary water storage due to the operations of the Diversion need to be assessed**.

The 98 storage areas evaluated in this study exceeded the general scope of the staging area as previously defined by the U.S. Army Corps of Engineers. Despite the expanded geography of lands that may be potentially impacted, potential effects for substantial acreage within the study region was not included in this study. All lands impacted by temporary water storage associated With the Diversion should be assessed. Those areas may include lands with hydrology impacts less than the Federal threshold for mitigation. Some of those lands are currently classified as 'cross-section' areas in the hydrology modeling. Producers operating in those areas will have no less desire to understand the hydrology effects and potential economic risk than producers operating in the storage areas identified in this study.

-) **Insurance Implications**

Evaluate the potential loss of insurance indemnities during flood years and potential effects of reduced yields in flood years on adjustments to a producer's annual production history. Implications associated with effects on Federal crop insurance could be substantial.

-) **Improve upon Key Assumptions**

Study results are sensitive to dry-down assumptions. The days required for dry-down and clean-up was a static assumption, but should be re-examined to evaluate if dry-down periods can be statistically linked to planting rates or related to weather differences generally observed between the months of April and May.

Refinement in general data may require cooperation from producers operating within the staging area or cooperation from government agencies (e.g., Risk Management Service). County- or state-level information for crop yields, planting periods, planting rates and other agricultural factors was used in this assessment. More refined data, specific to the general staging area, would provide more precise estimates of the economic effects.

-) **Variability of Effects at Producer Level Highlight Need for a Fair, Flexible, and Comprehensive Compensation Policy**

This study demonstrates the complexity of framing and measuring the impacts of temporary water storage on agricultural producers. The FM Diversion Authority should continue to evaluate alternative compensation adjustments and mitigation strategies. Potential elements could include relieving risk to tenant producers, not just landowners. A compensation plan addressing full damages and including all affected parties would help alleviate the risk and financial concerns associated with temporary water storage.

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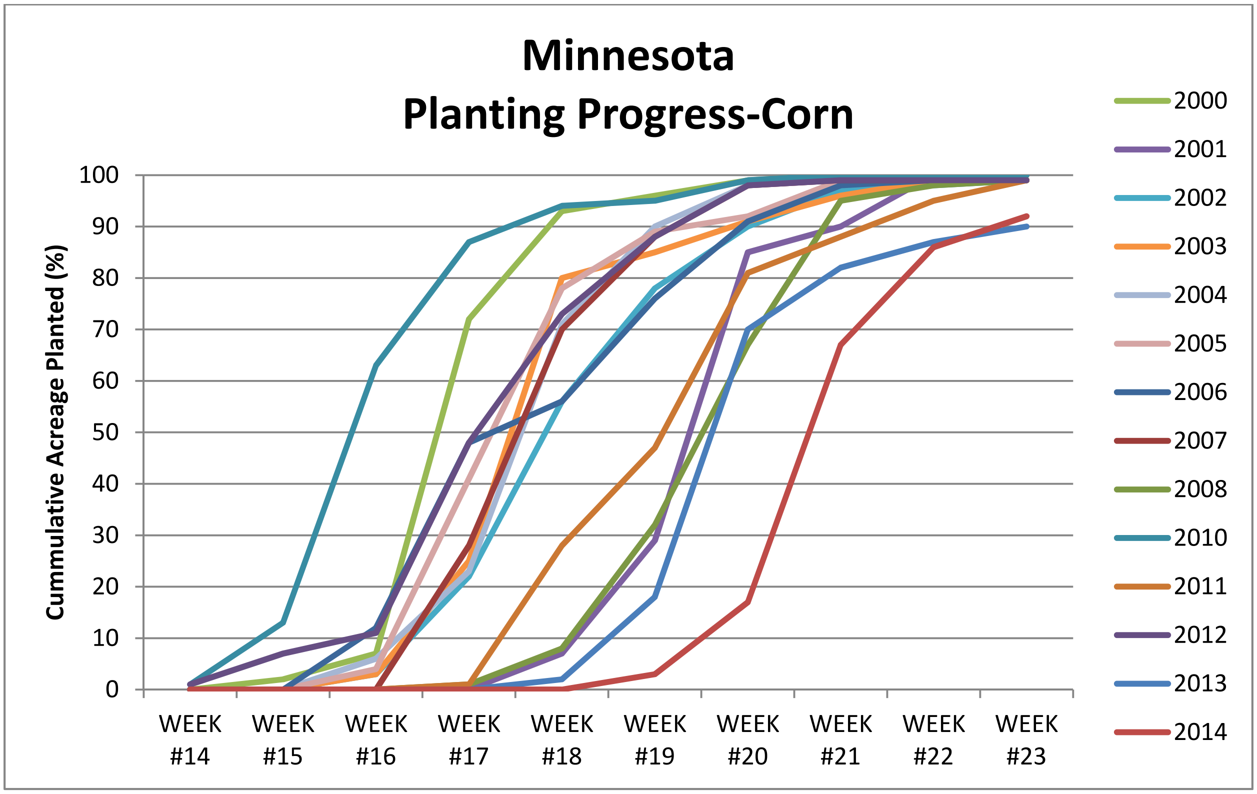
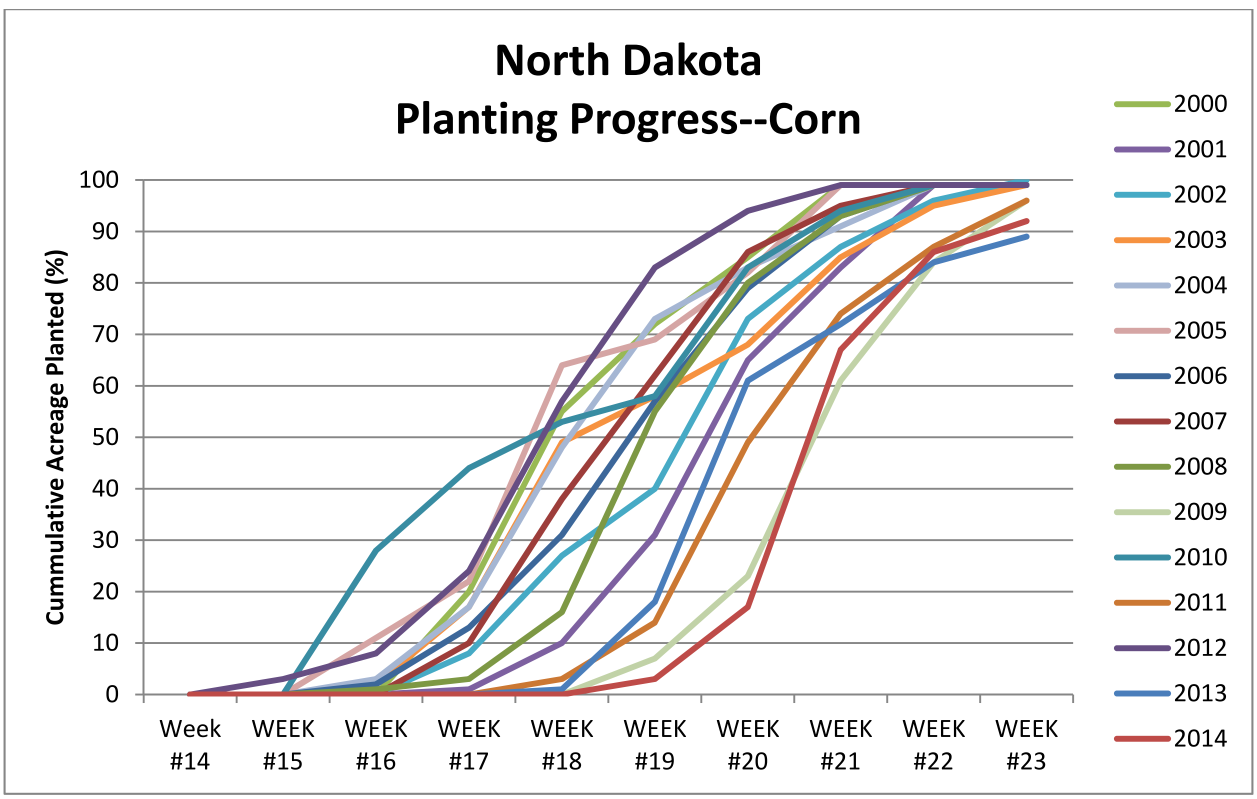
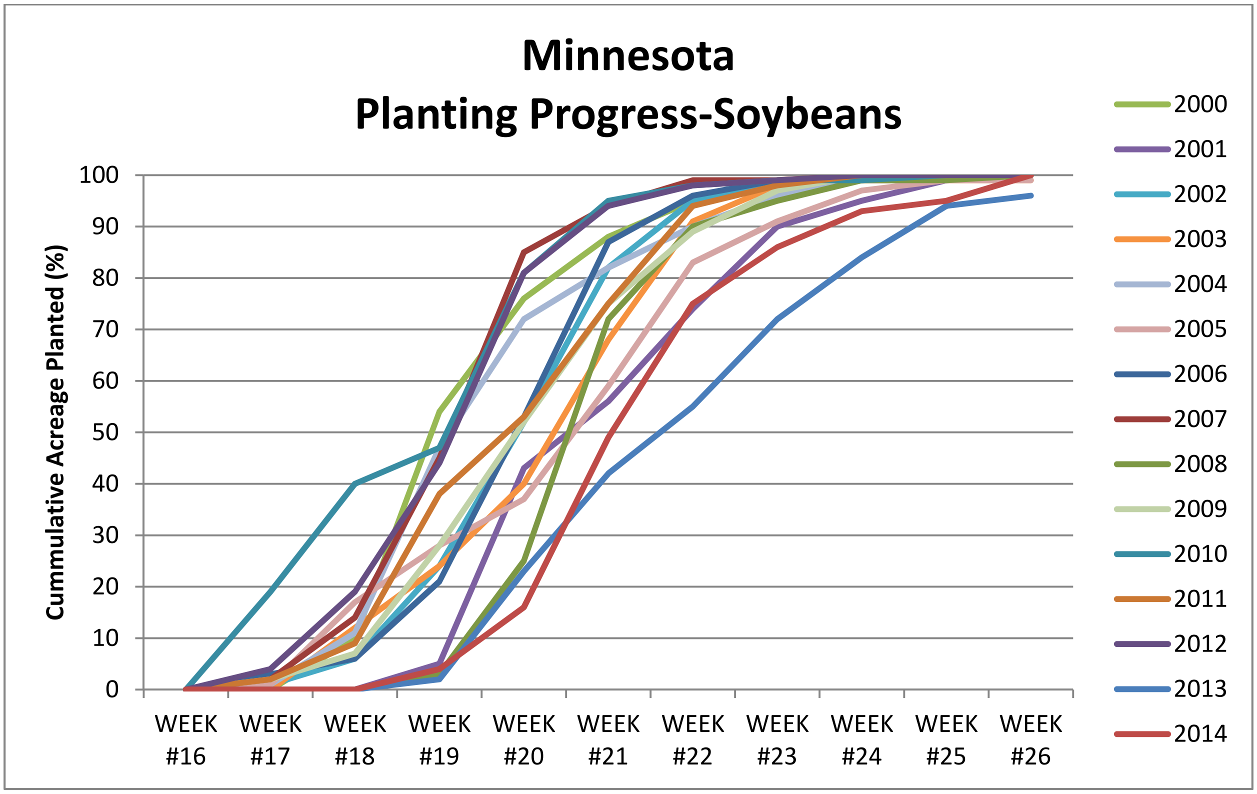
Appendix A
Planting Progress for Corn, Soybeans, Wheat, and Sugarbeets
Minnesota and North Dakota
2000 through 2014



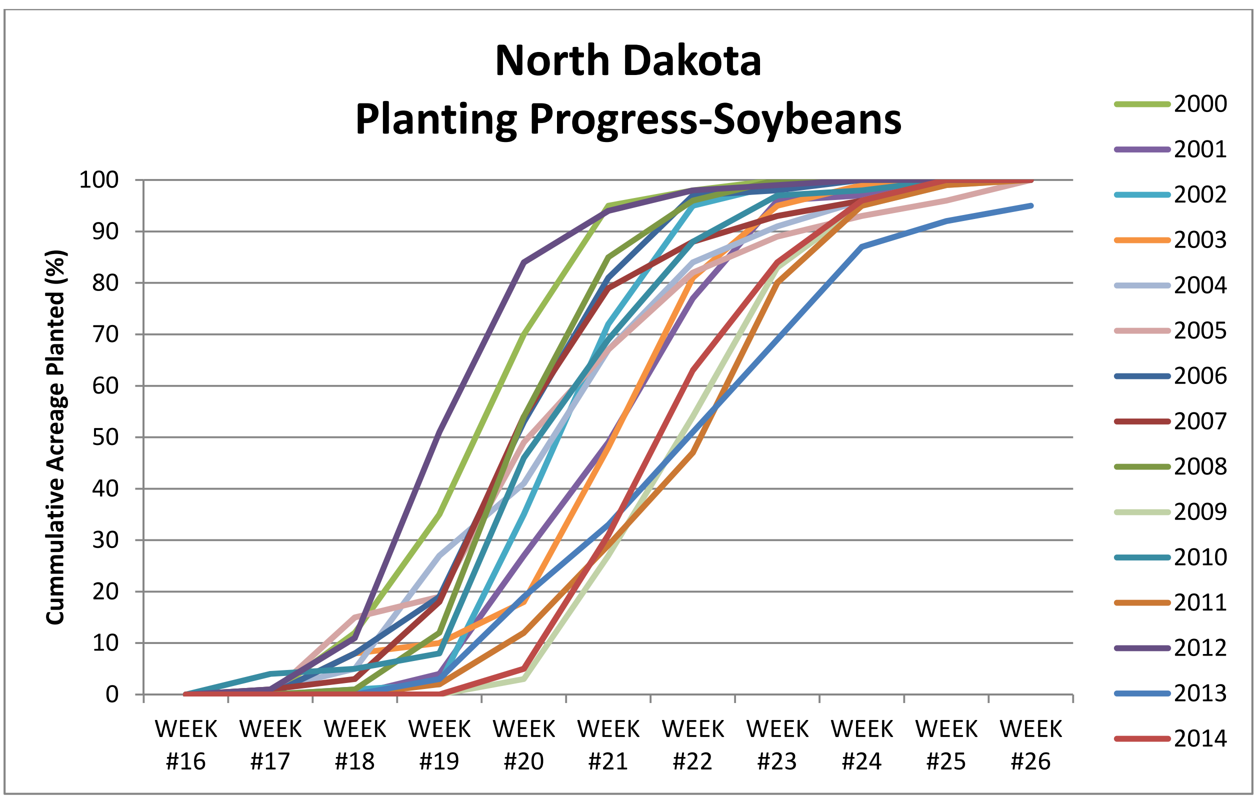
Appendix Figure A1. Planting Progress, Corn, Minnesota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



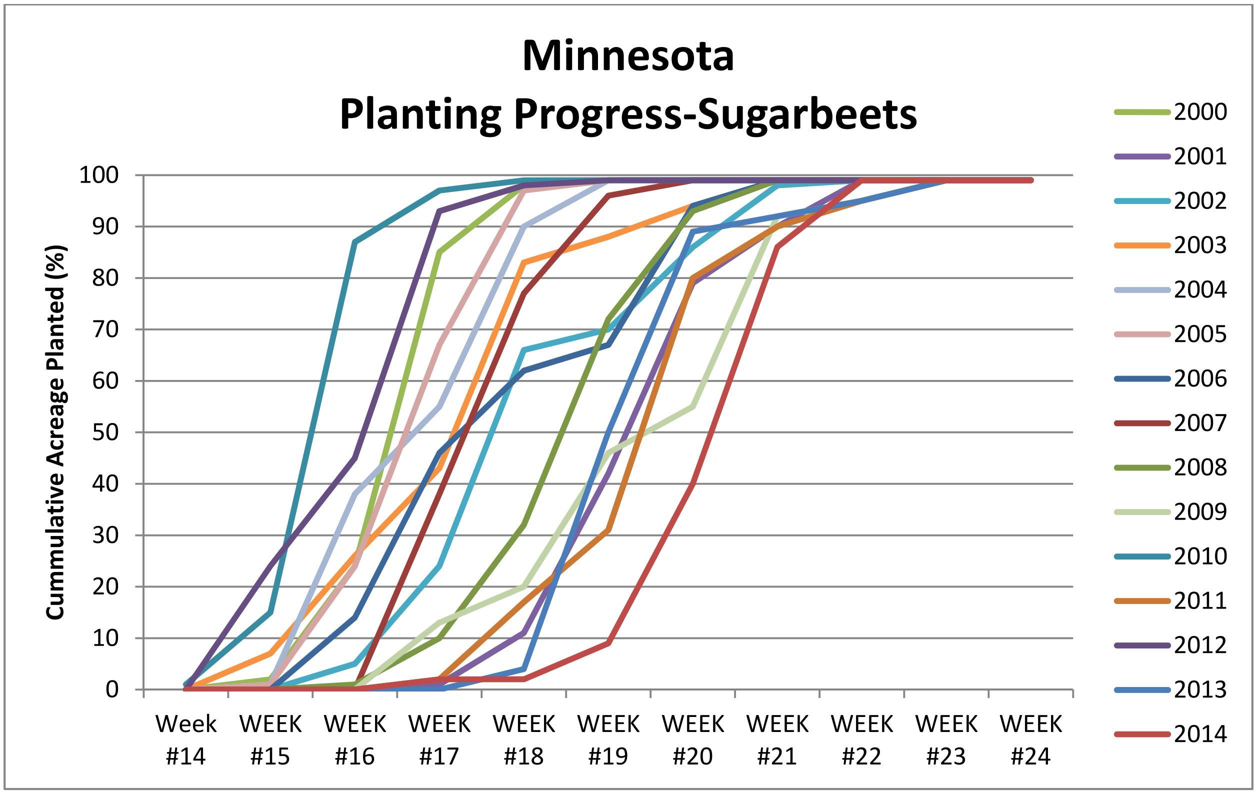
Appendix Figure A2. Planting Progress, Corn, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



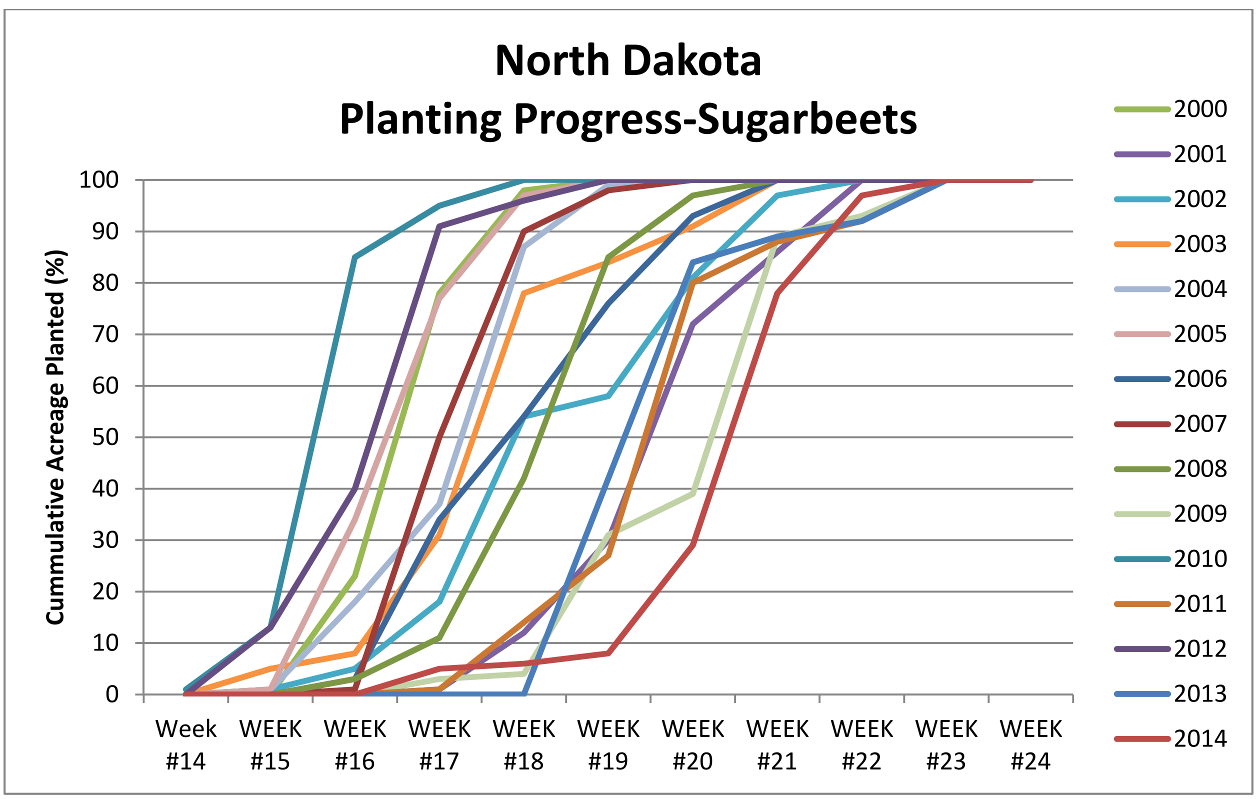
Appendix Figure A3. Planting Progress, Soybeans, Minnesota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



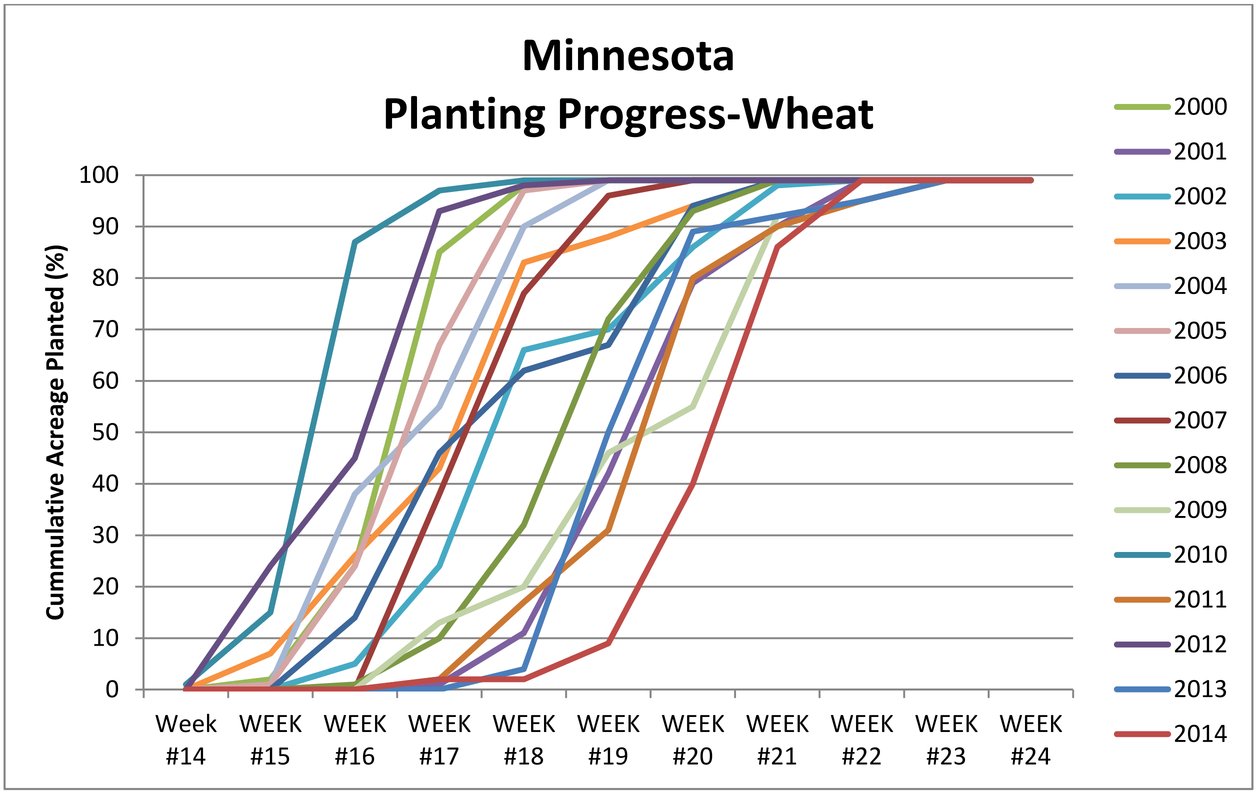
Appendix Figure A4. Planting Progress, Soybeans, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



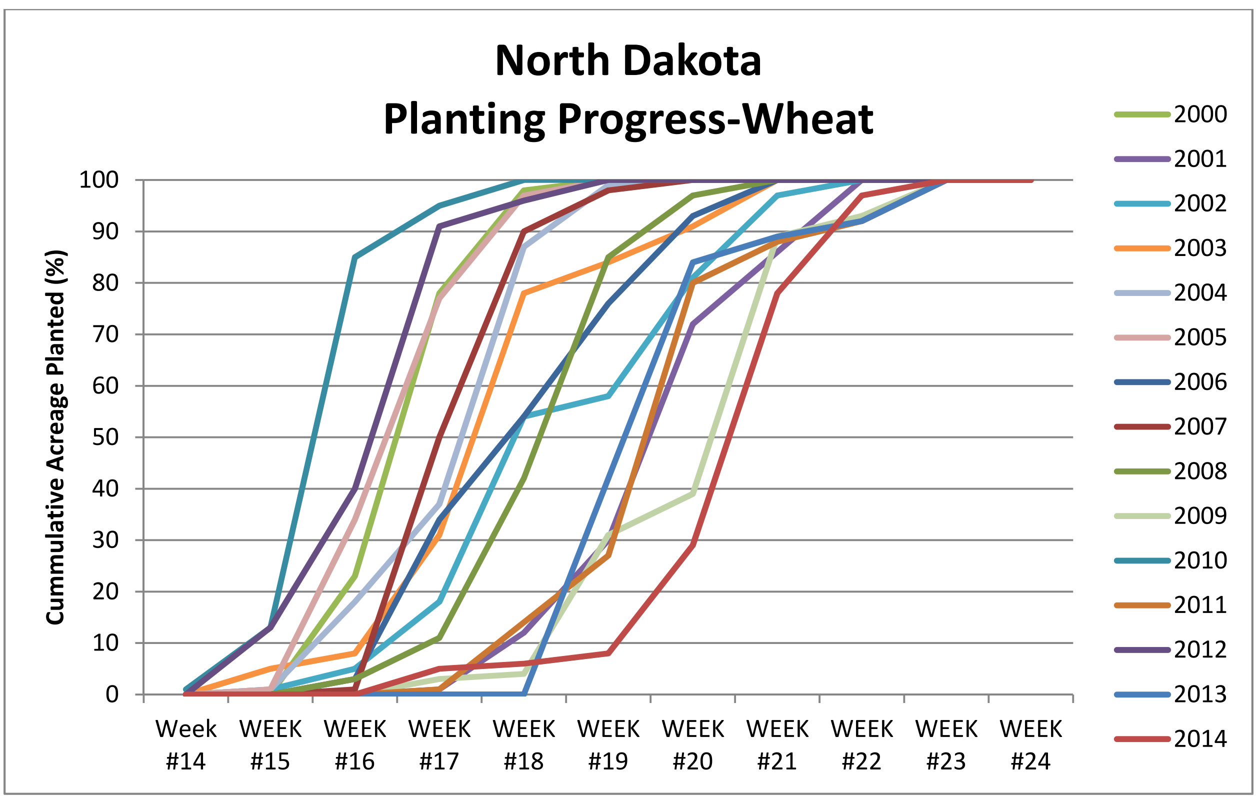
Appendix Figure A5. Planting Progress, Sugarbeets, Minnesota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



Appendix Figure A6. Planting Progress, Sugarbeets, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



Appendix Figure A7. Planting Progress, Wheat, Minnesota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



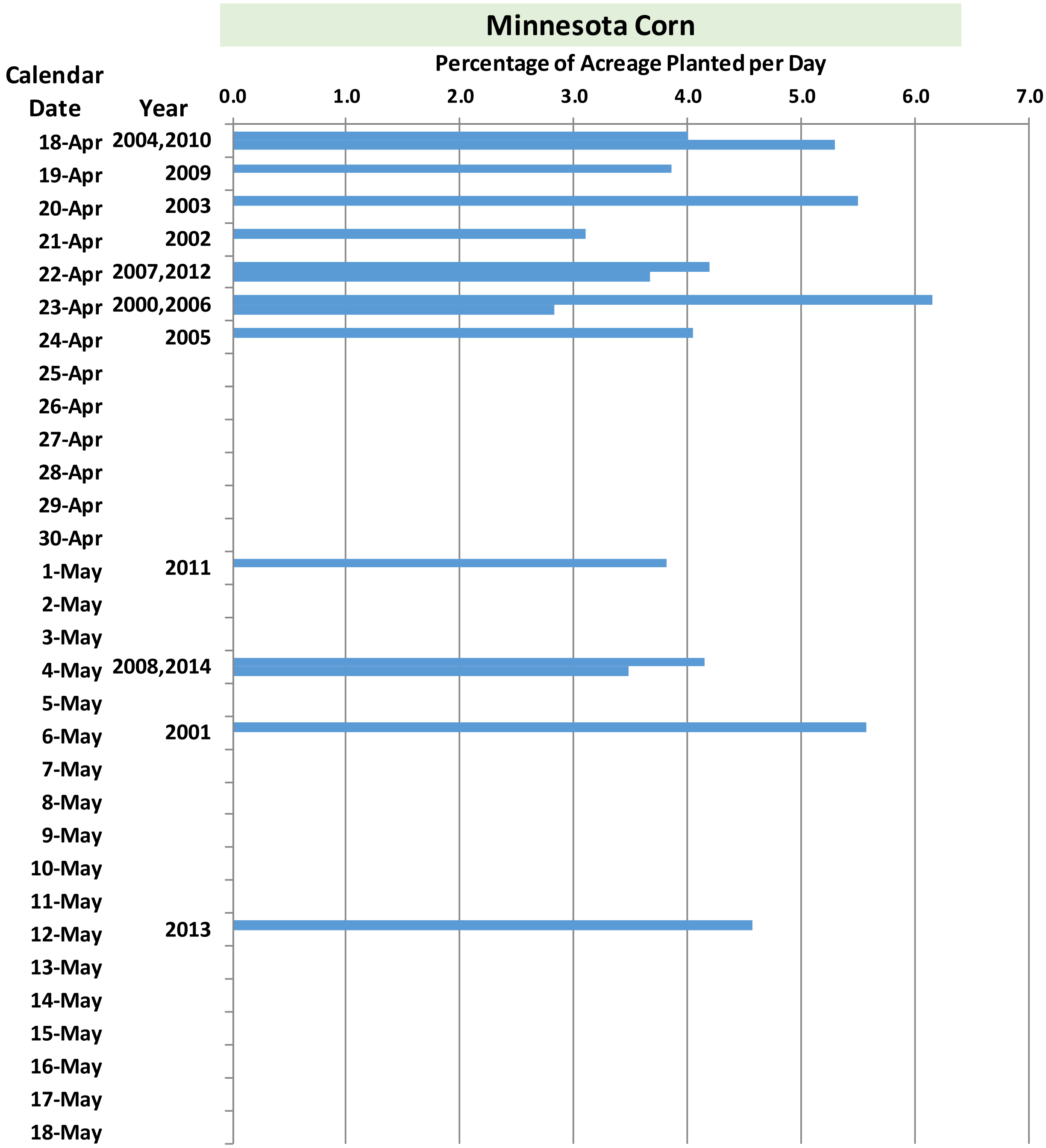
Appendix Figure A8. Planting Progress, Wheat, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

Appendix B

Planting Rates for Corn, Soybeans, Wheat, and Sugarbeets Based on Progress Between 20 Percent to 80 Percent of Acreage Planted

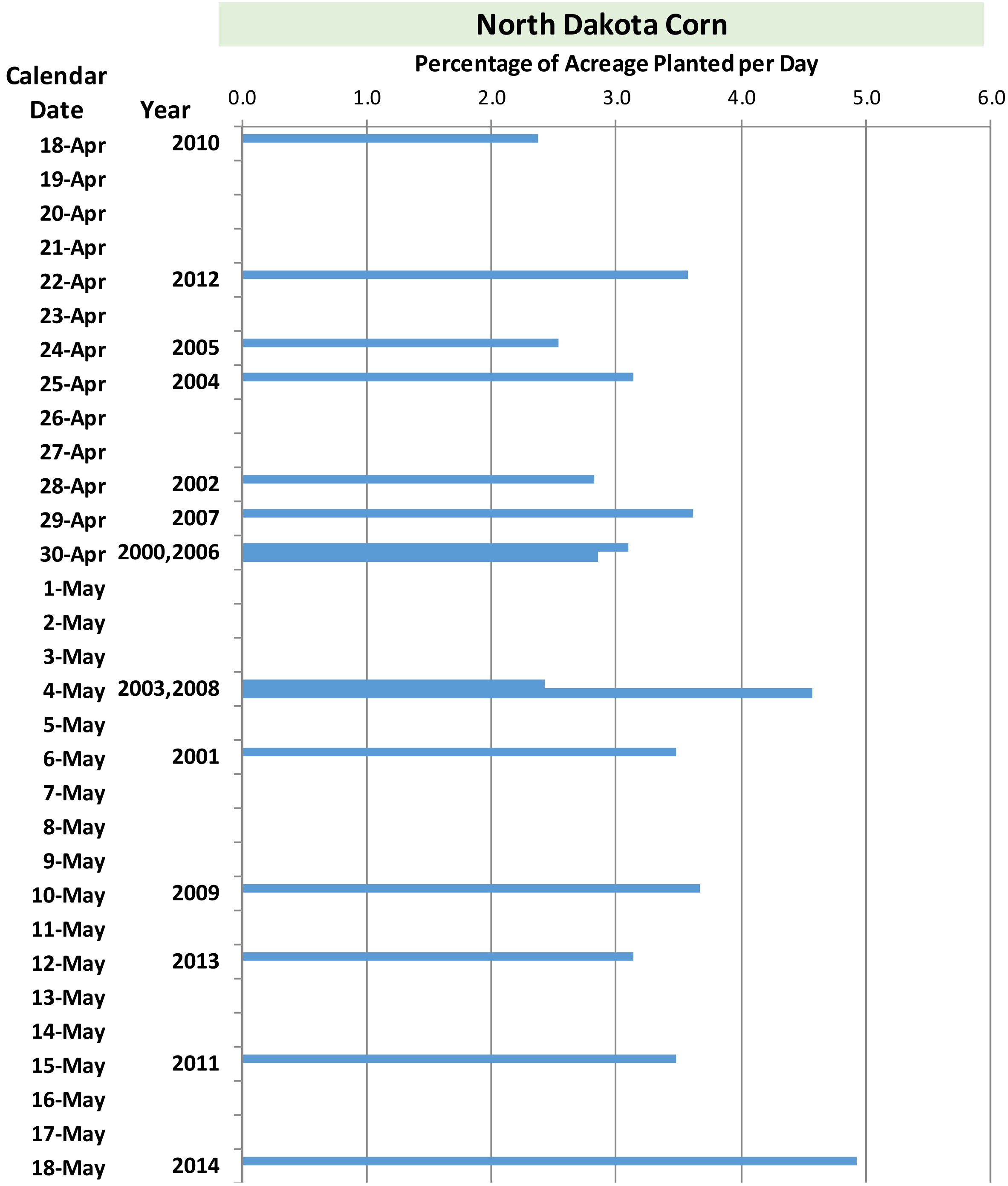
Minnesota and North Dakota

2000 through 2014

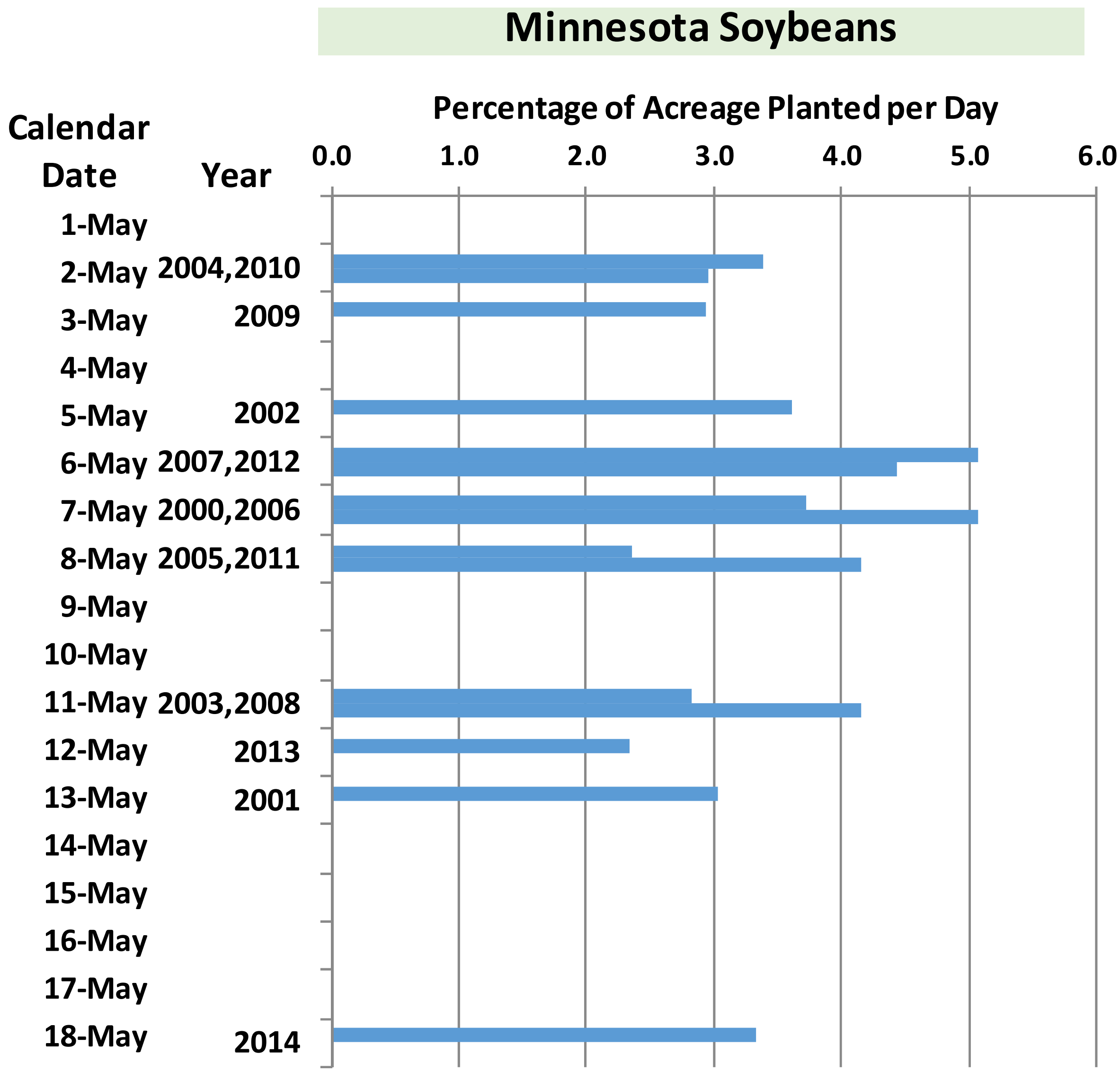


Appendix Figure B1. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Corn, Minnesota, 2000 through 2014.

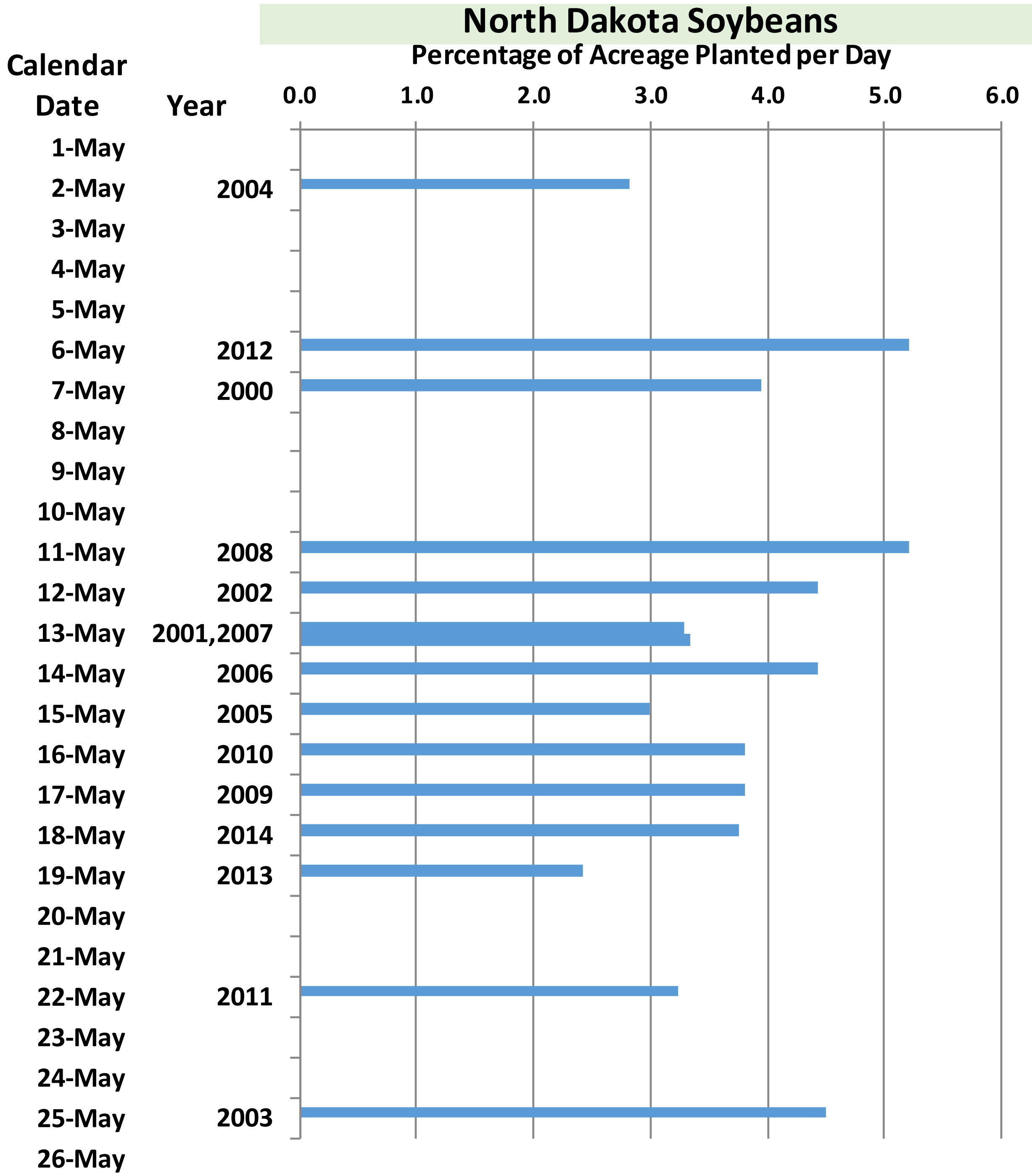
Source: National Agricultural Statistics Service (2015).



Appendix Figure B2. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Corn, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).

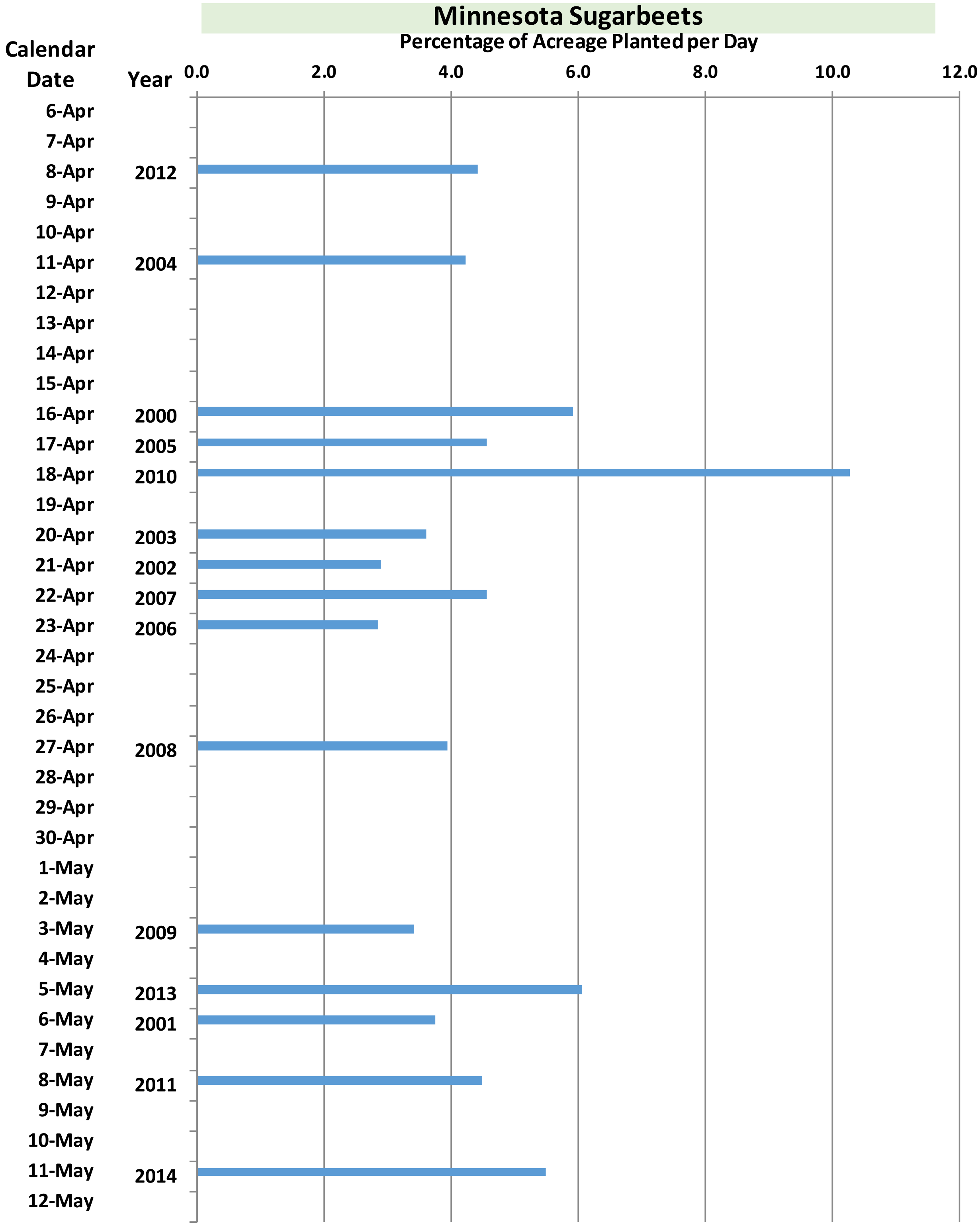


Appendix Figure B3. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Soybeans, Minnesota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



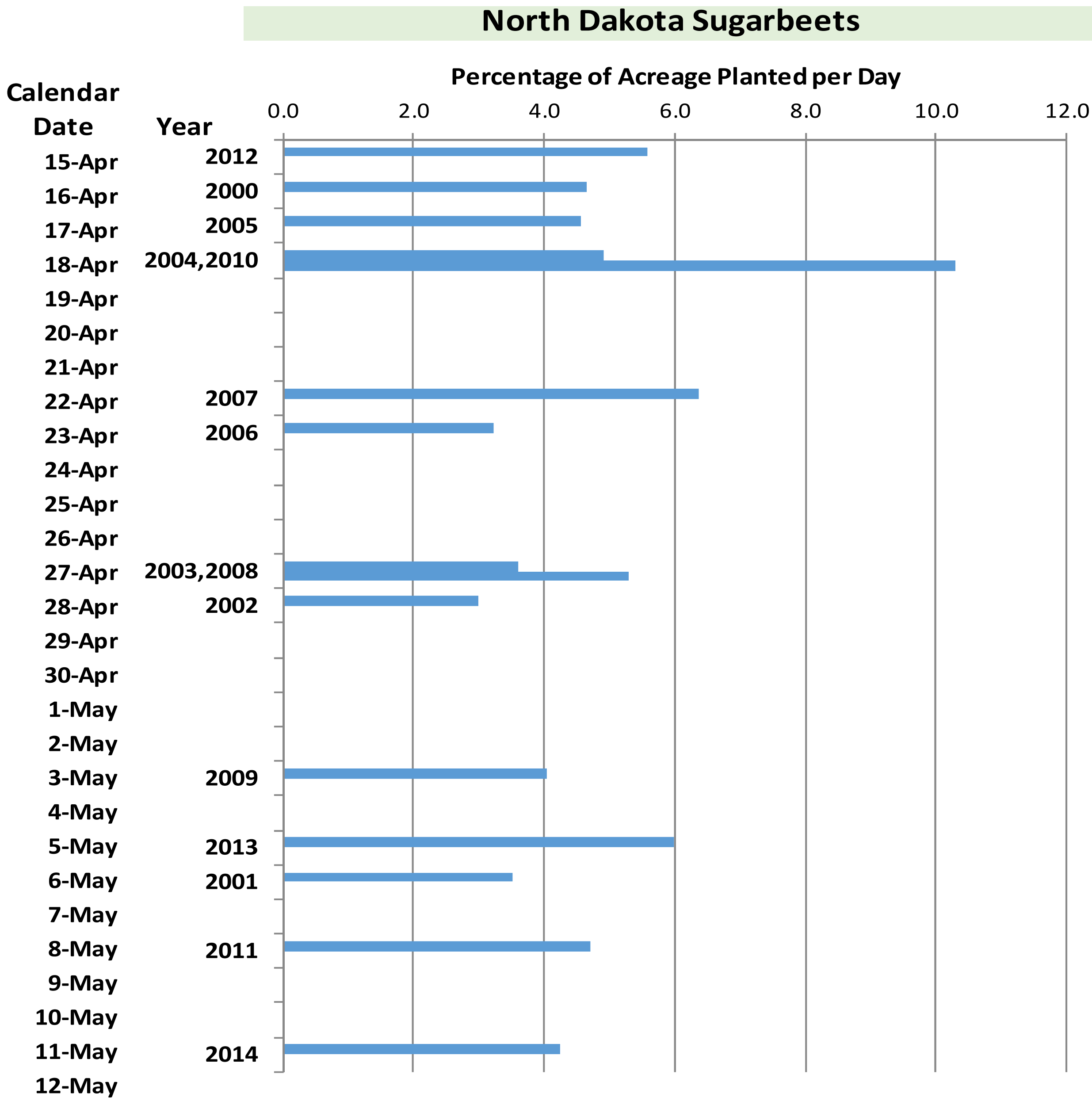
Appendix Figure B4. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Soybeans, North Dakota, 2000 through 2014.

Source: National Agricultural Statistics Service (2015).

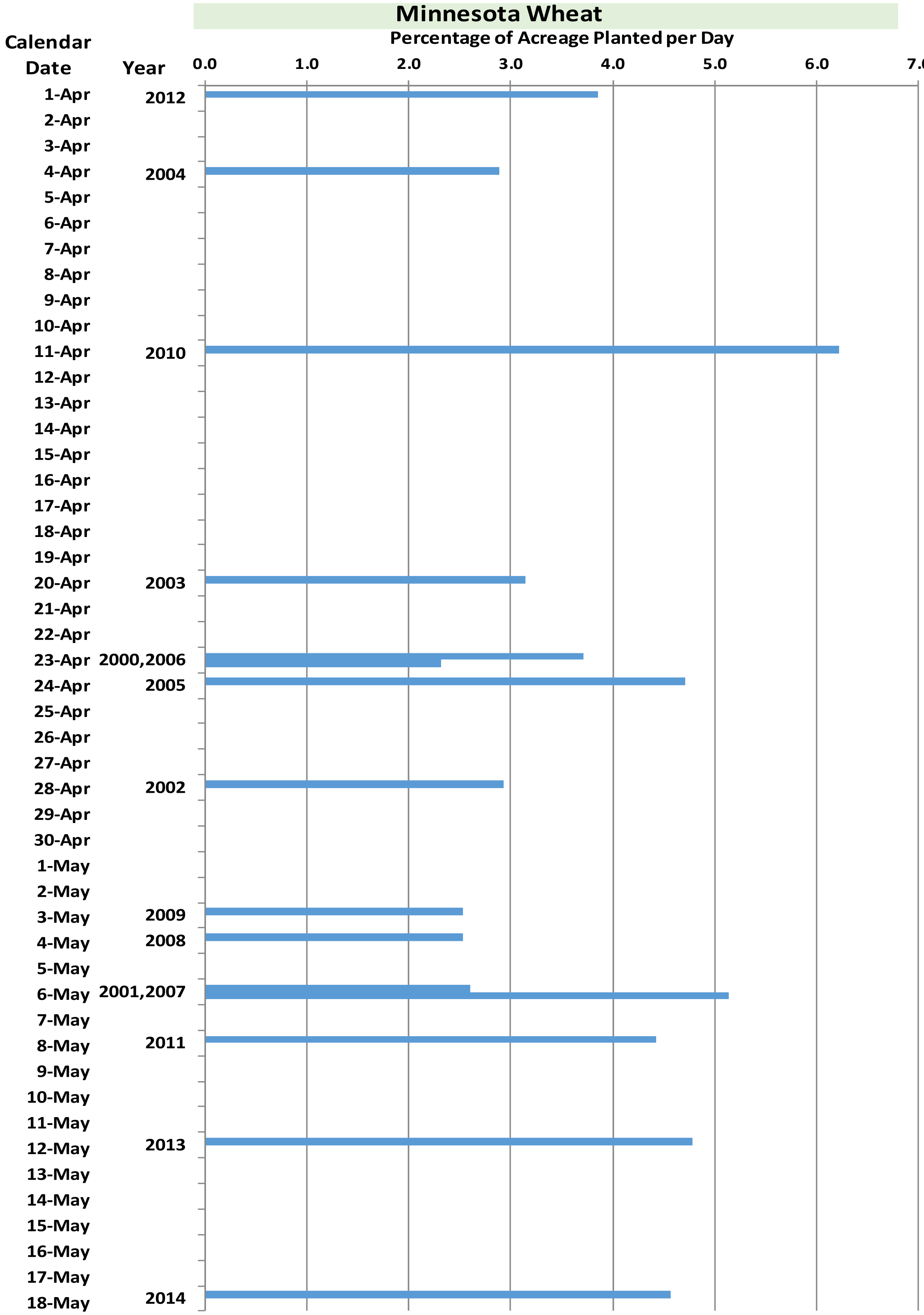


Appendix Figure B5. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Sugarbeets, Minnesota, 2000 through 2014.

Source: National Agricultural Statistics Service (2015).

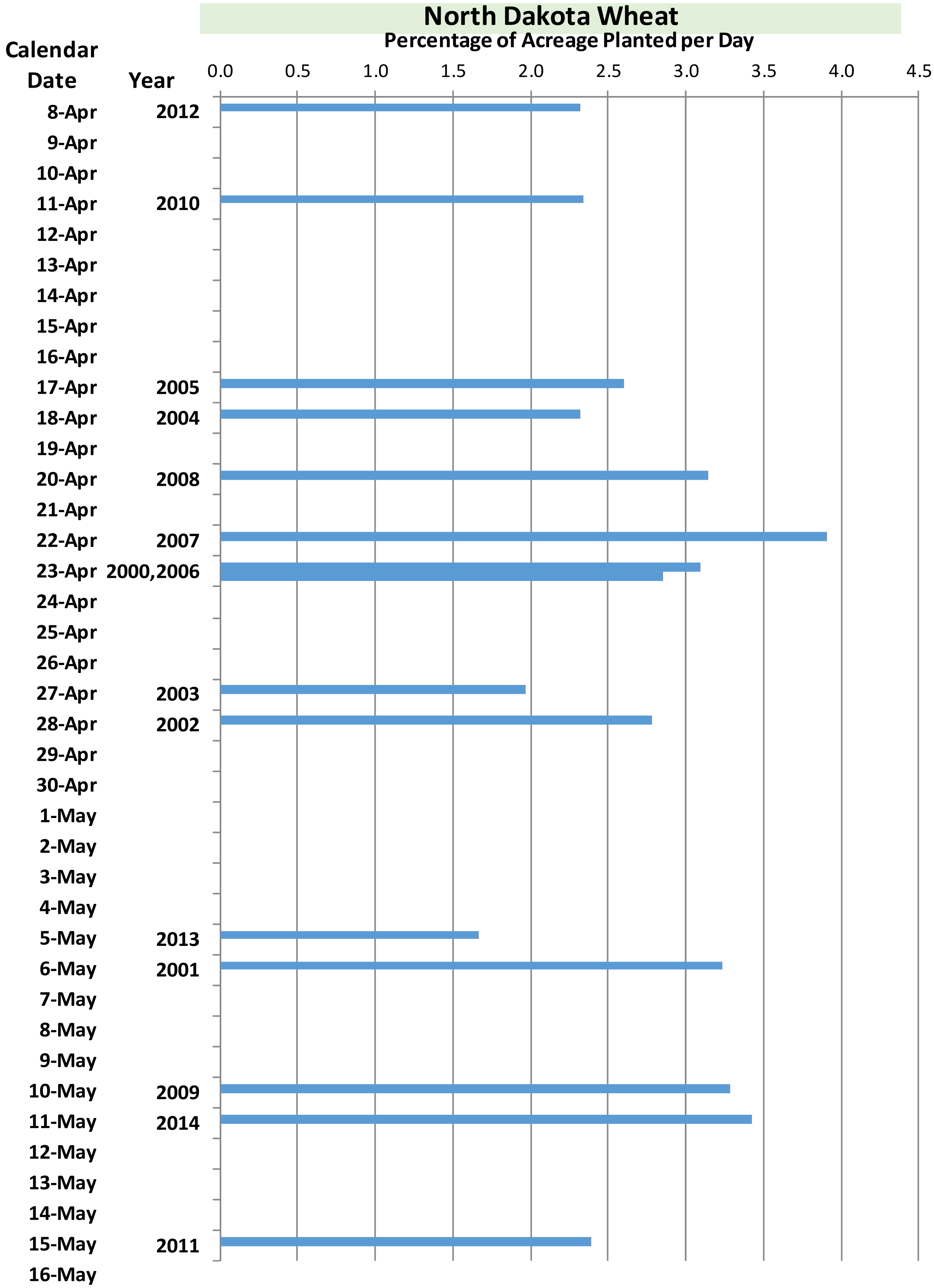


Appendix Figure B6. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Sugarbeets, North Dakota, 2000 through 2014.
Source: National Agricultural Statistics Service (2015).



Appendix Figure B7. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Wheat, Minnesota, 2000 through 2014.

Source: National Agricultural Statistics Service (2015).



Appendix Figure B8. Average Daily Planting Rates and Calendar Dates for 20 Percent to 80 Percent of Planting Progress, Wheat, North Dakota, 2000 through 2014.

Source: National Agricultural Statistics Service (2015).

Appendix C
Hydrology Data for Storage Areas, With and Without Diversion Conditions,
10-year, 25-year, 50-year, 100-year, 500-year, and 1997-like Flood Events
FM Diversion Staging Area

Appendix Table C1. Storage Area Data, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling							
Storage Area	Section	Township	Range	County	State	Approximate Field Elevation[a]	Acres
CHRSA01	26	137	49	Cass	ND	915.0	307
CHRSA02	25	137	49	Cass	ND	914.5	305
CHRSA03	35	137	49	Cass	ND	919.5	304
CHRSA04	36	137	49	Cass	ND	918.0	284
CHRSA05	2 & 3	136	49	Richland	ND	921.0	320
CHRSA06	2	136	49	Richland	ND	921.5	117
CHRSA07	2	136	49	Richland	ND	913.0	151
CHRSA08	2	136	49	Richland	ND	918.5	161
CHRSA09	11	136	49	Richland	ND	922.5	301
CHRSA10	11	136	49	Richland	ND	920.5	326
CHRSA11	14	136	49	Richland	ND	924.5	305
CHRSA12	14	136	49	Richland	ND	924.5	327
CHRSA13	13	136	49	Richland	ND	915.0	629
CHRSA14	23	136	49	Richland	ND	924.0	317
CHRSA15	23	136	49	Richland	ND	919.0	324
CHRSA16	24	136	49	Richland	ND	917.0	629
CHRSA17	18 & 19	136	48	Richland	ND	919.5	839
WLVSA27	5	137	48	Clay	MN	911.0	430
WLVSA28	4	137	48	Clay	MN	913.0	290
WLVSA29	3 & 4	137	48	Clay	MN	913.0	935
WLVSA30	2	137	48	Clay	MN	915.5	629
WLVSA31	1 & 6	137	48 & 47	Clay	MN	919.0	1266
WLVSA32	12 & 7	137	48 & 47	Clay	MN	919.5	1270
WLVSA33	11	137	48	Clay	MN	915.0	631
WLVSA34	9	137	48	Clay	MN	913.0	326
WLVSA34a	10	137	48	Clay	MN	915.0	627
WLVSA35	8	137	48	Clay	MN	905.0	409
WLVSA36	17	137	48	Clay	MN	909.0	374
WLVSA37	17	137	48	Clay	MN	910.0	249
WLVSA38	16	137	48	Clay	MN	912.0	222
WLVSA39	15	137	48	Clay	MN	918.5	469
WLVSA40	14	137	48	Clay	MN	918.5	633
WLVSA41	13 & 18 & 17	137	48 & 47	Clay	MN	921.0	1466
WLVSA42	24	137	48	Clay	MN	921.0	631
WLVSA42a	19	137	47	Clay	MN	922.0	644
WLVSA43	23	137	48	Clay	MN	921.0	635
WLVSA44	22	137	48	Clay	MN	922.0	179
WLVSA45	21	137	48	Clay	MN	913.0	309
- continued -							

Appendix Table C1. Continued							
Storage Area	Section	Township	Range	County	State	Approximate Field Elevation[a]	Acres
WLVSA46	20	137	48	Clay	MN	913.0	630
WLVSA47	29	137	48	Clay	MN	913.0	625
WLVSA48	28	137	48	Clay	MN	920.0	308
WLVSA49	28	137	48	Clay	MN	920.0	328
WLVSA50	26	137	48	Clay	MN	922.0	630
WLVSA51	25	137	48	Clay	MN	923.5	634
WLVSA51a	30	137	47	Clay	MN	923.0	642
WLVSA53	35	137	48	Clay	MN	922.0	638
WLVSA54	33	137	48	Clay	MN	921.5	334
WLVSA55	33	137	48	Clay	MN	921.0	302
WLVSA56	32	137	48	Clay	MN	915.0	629
WLVSA57	5	136	48	Wilkin	MN	921.0	210
WLVSA58	5	136	48	Wilkin	MN	921.0	173
WLVSA59	5	136	48	Wilkin	MN	922.0	227
WLVSA63	8	136	48	Wilkin	MN	922.0	228
WLVSA64	8	136	48	Wilkin	MN	922.0	400
WLVSA65	17	136	48	Wilkin	MN	919.0	127
WLVSA66	17	136	48	Wilkin	MN	923.5	212
WLVSA67	16 & 17	136	48	Wilkin	MN	921.5	726
WLVSA72	21	136	48	Wilkin	MN	924.5	593
WRSA284	6	136	49	Richland	ND	923.0	597
WRSA289	32	137	49	Cass	ND	922.0	629
WRSA294	29	137	49	Cass	ND	919.5	625
WRSA299	20	137	49	Cass	ND	911.0	627
WRSA300	21	137	49	Cass	ND	908.0	626
WRSA302	23 & 24	137	49	Cass	ND	912.0	404
WRSA304	17	137	49	Cass	ND	911.5	635
WRSA305A	9	137	49	Cass	ND	910.5	225
WRSA305B	9	137	49	Cass	ND	908.5	408
WRSA305C	15 & 16	137	49	Cass	ND	906.0	808
WRSA305D	10	137	49	Cass	ND	913.0	432
WRSA306	13 & 14	137	49	Cass	ND	910.0	619
WRSA307	13	137	49	Cass	ND	910.0	254
WRSA309	8	137	49	Cass	ND	914.0	636
WRSA311	11	137	49	Cass	ND	907.0	305
WRSA312	12	137	49	Cass	ND	905.0	631
WRSA314	5	137	49	Cass	ND	912.5	619
WRSA315	4	137	49	Cass	ND	910.5	613
- continued -							

Appendix Table C1. Continued							
Storage Area	Section	Township	Range	County	State	Approximate Field Elevation[a]	Acres
WRSA316	3	137	49	Cass	ND	910.5	611
WRSA317A	1	137	49	Cass	ND	908.0	353
WRSA317B	1	137	49	Cass	ND	906.0	230
WRSA350	11	137	49	Cass	ND	910.0	274
WRSA351	14	137	49	Cass	ND	908.0	309
WRSA352	23	137	49	Cass	ND	910.5	297
WRSA353	26	137	49	Cass	ND	917.0	292
WRSA354	35	137	49	Cass	ND	918.0	295
WRSA355	3	136	49	Richland	ND	914.5	415
WRSA356	10	136	49	Richland	ND	917.5	622
WRSA357	15	136	49	Richland	ND	919.0	614
WRSA358	22	136	49	Richland	ND	921.0	492
WRSA361	2	137	49	Cass	ND	907.0	192
WRSA363	15	137	49	Cass	ND	911.0	268
WRSA364	22	137	49	Cass	ND	912.0	252
WRSA373	17	136	49	Richland	ND	927.5	632
WRSA378	8	136	49	Richland	ND	926.0	156
WRSA383	5	136	49	Richland	ND	923.5	153
WRSA384	8	136	49	Richland	ND	925.0	155
WRSA389	5	136	49	Richland	ND	921.5	151
WRSA390	33	137	49	Cass	ND	913.0	269
WRSA907	28	137	49	Cass	ND	913.0	394

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C2. Duration of Water Inundation, by Storage Area, by Flood Event Frequency for With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area

		Days of Water above Storage Area Elevation										
	Approx.	Existing Conditions						With Diversion Staging Area				
Storage Area	Field Elevation[a]	10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
CHRSA01	915.0	0	0	0	0	5		0	7.5	9	11.5	11.5
CHRSA02	914.5	0	0	0	2	10		0	9	11	13	13.5
CHRSA03	919.5	0	0	0	0	0		0	1.5	4.5	6.5	7.5
CHRSA04	918.0	0	0	0	0	7		0	6	8.5	10.5	11.5
CHRSA05	921.0	0	0	0	0	6.5		0	0	3	5	7.5
CHRSA06	921.5	0	0	0	0	6		0	0	2.5	4.5	7
CHRSA07	913.0	0	5	7.5	8.5	12.5		0	10.5	12	15	15
CHRSA08	918.5	0	0	0	2	7		0	5	7	8.5	10
CHRSA09	922.5	0	0	0	2	6		0	0	0	2.5	6
CHRSA10	920.5	0	0	0	0	5		0	0	4.5	6	8
CHRSA11	924.5	0	0	0	0	5		0	0	0	0	4.5
CHRSA12	924.5	0	0	0	0	5		0	0	0	0	6
CHRSA13	915.0	0	5.5	8	9	13.5		0	9.5	11.5	14	15.5
CHRSA14	924.0	0	0	0	0	5		0	0	0	0	5.5
CHRSA15	919.0	0	0	4	5	9.5		0	6	7.5	10	11.5
CHRSA16	917.0	0	3.5	6	7	11		0	7.5	9.5	12	14
CHRSA17	919.5	0	2	4.5	5.5	9.5		0	6	8	10	11.5
WLVSA27	911.0	0	0	4.5	6	9		0	11.5	12.5	15	14.5
WLVSA28	913.0	0	0	0	2.5	6.5		0	9.5	10.5	13	13
WLVSA29	913.0	0	0	0	2.5	6.5		0	9.5	10.5	13	13
WLVSA30	915.5	0	0	0	0	0		0	7.5	9.5	11	11.5
WLVSA31	919.0	0	0	0	0	0		0	2	5	7	7.5
WLVSA32	919.5	0	0	0	0	0		0	1.5	4.5	7.5	8.5
WLVSA33	915.0	0	0	0	0	1.5		0	8.5	10	12	12.5
WLVSA34	913.0	0	0	2.5	4	7.5		0	9.5	10.5	13	13
WLVSA34a	915.0	0	0	0	0	1.5		0	8	9.5	11.5	12
WLVSA35	905.0	5	9	11	13	19.5		5	14.5	15	18	20
WLVSA36	909.0	0.5	6	8	9.5	14		0.5	13	13.5	16.5	17
WLVSA37	910.0	2.5	5.5	8	7.5	12		2.5	12	13	15.5	15.5
WLVSA38	912.0	2.5	3.5	6	6	9		2.5	11	12	14	14.5
WLVSA39	918.5	0	0	0	0	0		0	4.5	6.5	8.5	9
WLVSA40	918.5	0	0	0	0	0		0	4.5	7.5	9	9.5
WLVSA41	921.0	0	0	0	0	0		0	0	0	5	6.5
WLVSA42	921.0	0	0	0	0	0		0	0	0	5	5.5
WLVSA42a	922.0	0	0	0	0	0		0	0	0	2	3.5

- continued -

Appendix Table C2 Continued

		Days of Water above Storage Area Elevation									
		Existing Conditions					With Diversion Staging Area				
Storage Area	Approx. Field Elevation[a]	10-yr	25-yr	50-yr	100-yr	500-yr	10-yr	25-yr	50-yr	100-yr	500-yr
WLVSA43	921.0	0	0	0	0	0	0	0	0.5	4.5	5.5
WLVSA44	922.0	0	0	0	0	0	0	0	0	2	3.5
WLVSA45	913.0	3	3.5	5	5.5	7.5	3	10	11.5	13.5	13.5
WLVSA46	913.0	0	0	4	5	9.5	0	9.5	11	13	14
WLVSA47	913.0	0	3.5	6.5	7.5	11	0	10	11.5	14	15
WLVSA48	920.0	0	0	0	0	1.5	0	0	4.5	6	7
WLVSA49	920.0	0	0	0	0	2	0	0	4	6.5	7
WLVSA50	922.0	0	0	0	0	1	0	0	0	4	5
WLVSA51	923.5	0	0	0	0	0	0	0	0	0	1
WLVSA51a	923.0	0	0	0	0	0	0	0	0	0	2.5
WLVSA53	922.0	0	0	0	2	2.5	0	0	1	4.5	5.5
WLVSA54	921.5	0	0	0	0	2.5	0	0	0.5	4.5	6.5
WLVSA55	921.0	0	0	0	0	2.5	0	0	2.5	5	7
WLVSA56	915.0	0	2	4.5	5.5	9.5	0	8.5	10	12.5	13
WLVSA57	921.0	0	0	0	0.5	8	0	0	3.5	5.5	9.5
WLVSA58	921.0	0	0	0	0.5	8.5	0	0	3.5	5.5	9.5
WLVSA59	922.0	0	0	0	1	8.5	0	0	3	4.5	10.5
WLVSA63	922.0	0	0	0	2	7	0	0	3.5	5	9
WLVSA64	922.0	0	0	0	1.5	7	0	0	3.5	5	9
WLVSA65	919.0	0	0	3.5	4.5	8.5	0	5.5	7.5	9.5	11
WLVSA66	923.5	0	0	0	2	7	0	0	2.5	4	8
WLVSA67	921.5	2.5	3	4.5	5.5	7.5	2.5	3.5	6.5	7.5	9
WLVSA72	924.5	0	0	0	0	6	0	0	0	2	7
WRSA284	923.0	0	0	0	0	0	0	0	0	0	0
WRSA289	922.0	0	0	0	0	0	0	0	0	2	4
WRSA294	919.5	0	0	0	0	4.5	0	1.5	4	5.5	7.5
WRSA299	911.0	5	9	11	13	17.5	5	11.5	13.5	15.5	17
WRSA300	908.0	8	12	14	17.5	26	7.5	13	15	17.5	23.5
WRSA302	912.0	0	3	5.5	7	10.5	0	10.5	12	14	14
WRSA304	911.5	5	8.5	10	12.5	17	4	11.5	12.5	15	16.5
WRSA305A	910.5	6	9.5	11.5	14	19	5	11.5	13.5	15	17.5
WRSA305B	908.5	7.5	11.5	13.5	16.5	24	7.5	12.5	14.5	17	21.5
WRSA305C	906.0	10	14.5	17	22	33	9.5	15.5	17	21.5	32
WRSA305D	913.0	2.5	7	8.5	10.5	14.5	2	10.5	12	14	14.5
WRSA306	910.0	2	8	10	11.5	15.5	2	13	14.5	17	17.5
WRSA307	910.0	0	6	8	9.5	14	0	12.5	13.5	16	16.5

- continued -

Appendix Table C2. Continued												
		Days of Water above Storage Area Elevation										
		Existing Conditions						With Diversion Staging Area				
Storage Area	Approx. Field Elevation[a]	10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
WRSA309	914.0	0	5.5	7	9	12.5		0	9.5	11	13	13.5
WRSA311	907.0	6.5	10.5	12.5	15	21		6.5	15	16	18.5	19
WRSA312	905.0	8	12	14.5	17	26.5		8	15	16.5	18.5	23.5
WRSA314	912.5	0	2	4.5	7	9.5		0	10	11.5	13.5	14
WRSA315	910.5	0	0	5	7.5	10.5		3.5	11	12.5	14.5	14.5
WRSA316	910.5	3	8.5	10	12.5	16		3.5	11	12.5	14.5	15
WRSA317A	908.0	5.5	10	12	14	18.5		5	14.5	16	18	18.5
WRSA317B	906.0	3	8	10	12	17.5		3.5	14	14.5	17.5	18.5
WRSA350	910.0	2.5	8	10	12	15.5		2.5	13	15	17	17
WRSA351	908.0	5.5	10	12	13.5	18.5		5.5	14	16	18	18
WRSA352	910.5	0	8	10	11.5	15.5		0	12.5	14.5	16.5	16.5
WRSA353	917.0	0	0	2	4.5	7.5		0	6	7.5	9.5	10
WRSA354	918.0	0	4.5	6	8	11.5		0	7	8	10.5	12.5
WRSA355	914.5	5.5	9	11	13.5	18.5		5.5	11	13	15	18.5
WRSA356	917.5	4	8	9	12	16		4	9	11	13.5	16
WRSA357	919.0	2.5	6.5	8	10	14		2.5	7.5	9.5	12	14.5
WRSA358	921.0	0	4.5	6	8	11		0	5.5	7	9	11.5
WRSA361	907.0	6.5	10.5	12.5	15	21		6.5	14.5	16.5	18.5	19
WRSA363	911.0	0	8	9.5	11.5	15		0	12.5	14	16.5	16.5
WRSA364	912.0	0	7.5	9.5	11.5	14.5		0	12	13.5	15.5	15.5
WRSA373	927.5	0	0	0	0	0		0	0	0	0	0
WRSA378	926.0	0	0	0	0	3.5		0	0	0	0	4
WRSA383	923.5	0	0	0	0	0		0	0	0	0	0
WRSA384	925.0	0	0	0	0	4.5		0	0	0	0	4.5
WRSA389	921.5	0	0	3	5	8		0	0	4.5	6.5	8.5
WRSA390	913.0	5.5	9.5	11.5	14	19		5.5	11	13	15	18.5
WRSA907	913.0	3	7	9	11	15		3	10.5	12	14.5	15

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C3. Time from Activation of Staging Area to Inundation, by Storage Area, by Flood Event Frequency for With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated										
		Existing Conditions						With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
CHRSA01	915.0	0	0	0	0	4		0	3	2.5	2.5	2.5
CHRSA02	914.5	0	0	0	4.5	3.5		0	3	2.5	2.5	2.5
CHRSA03	919.5	0	0	0	0	0		0	5.5	4.5	4.5	4
CHRSA04	918.0	0	0	0	0	3.5		0	4.5	3.5	3.5	3
CHRSA05	921.0	0	0	0	0	3.5		0	0	4.5	4.5	3.5
CHRSA06	921.5	0	0	0	0	3.5		0	0	4.5	4	3.5
CHRSA07	913.0	0	2.5	2	2	2		0	2	1.5	1.5	1.5
CHRSA08	918.5	0	0	0	3.5	3		0	3.5	3	3	2.5
CHRSA09	922.5	0	0	0	0	3.5		0	0	0	5	4
CHRSA10	920.5	0	0	0	0	3.5		0	0	3.5	3.5	3
CHRSA11	924.5	0	0	0	0	3.5		0	0	0	0	4
CHRSA12	924.5	0	0	0	0	3		0	0	0	0	3
CHRSA13	915.0	0	2	1.5	1.5	1.5		0	2	1.5	1.5	1.5
CHRSA14	924.0	0	0	0	0	3.5		0	0	0	0	3.5
CHRSA15	919.0	0	0	2.5	2.5	2		0	2.5	2.5	2	2
CHRSA16	917.0	0	2.5	2	2	2		0	2.5	2	2	1.5
CHRSA17	919.5	0	3	2.5	2.5	2		0	2.5	2	2	2
WLVSA27s	911.0	0	0	3.5	3.5	3.5		0	1.5	1.5	1.5	1.5
WLVSA28s	913.0	0	0	0	4.5	4		0	2	2	2	2
WLVSA29s	913.0	0	0	0	4.5	4		0	2	2	2	2
WLVSA30s	915.5	0	0	0	0	0		0	3	2.5	3	3
WLVSA31s	919.0	0	0	0	0	0		0	5.5	4.5	4.5	4.5
WLVSA32	919.5	0	0	0	0	0		0	5.5	4.5	4.5	4.5
WLVSA33	915.0	0	0	0	0	5		0	2.5	2.5	2.5	2.5
WLVSA34	913.0	0	0	4	4	3.5		0	2	2	2	2
WLVSA34a	915.0	0	0	0	0	5		0	2.5	2.5	2.5	2.5
WLVSA35	905.0	3	2	1.5	2	1.5		3	1	1	0.5	0.5
WLVSA36	909.0	5	3	2.5	2.5	2.5		5	1.5	1.5	1.5	1
WLVSA37	910.0	3	2	1.5	3	2.5		3	1.5	1.5	1.5	1
WLVSA38	912.0	3	1.5	1.5	3	3		3	1.5	1.5	2	1.5
WLVSA39	918.5	0	0	0	0	0		0	4	3.5	3.5	3.5
WLVSA40	918.5	0	0	0	0	0		0	4.5	3.5	4	4
WLVSA41	921.0	0	0	0	0	0		0	0	0	6	5.5
WLVSA42	921.0	0	0	0	0	0		0	0	0	5	5
WLVSA42a	922.0	0	0	0	0	0		0	0	0	6.5	6
WLVSA43	921.0	0	0	0	0	0		0	0	6	5	5

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Appendix Table C3. Continued

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated									
		Existing Conditions					With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr	10-yr	25-yr	50-yr	100-yr	500-yr
WLVSA44	922.0	0	0	0	0	0	0	0	0	6	5.5
WLVSA45	913.0	2.5	1.5	1.5	3	3.5	2.5	1.5	1.5	2	2
WLVSA46	913.0	0	0	4	4	3	0	2.5	2	2.5	2
WLVSA47	913.0	0	3	2.5	2.5	2.5	0	2	2	2	1.5
WLVSA48	920.0	0	0	0	0	5	0	0	4	4	4
WLVSA49	920.0	0	0	0	0	5	0	0	4.5	4	4
WLVSA50	922.0	0	0	0	0	5.5	0	0	0	4.5	4.5
WLVSA51	923.5	0	0	0	0	0	0	0	0	0	6
WLVSA51a	923.0	0	0	0	0	0	0	0	0	0	5.5
WLVSA53	922.0	0	0	0	4	4.5	0	0	3	4	4
WLVSA54	921.5	0	0	0	0	4.5	0	0	5.5	4.5	4
WLVSA55	921.0	0	0	0	0	4.5	0	0	4.5	4	3.5
WLVSA56	915.0	0	3.5	3	3	2.5	0	2.5	2	2	2
WLVSA57	921.0	0	0	0	4.5	3	0	0	4	3.5	3
WLVSA58	921.0	0	0	0	4.5	3	0	0	4	3.5	3
WLVSA59	922.0	0	0	0	4.5	3.5	0	0	4	4	3
WLVSA63	922.0	0	0	0	3.5	3	0	0	3.5	3.5	2.5
WLVSA64	922.0	0	0	0	3.5	3	0	0	3.5	3.5	2.5
WLVSA65	919.0	0	0	3	3	2.5	0	3	2.5	2.5	2
WLVSA66	923.5	0	0	0	3.5	2.5	0	0	3.5	3.5	2.5
WLVSA67	921.5	2.5	1.5	1	2.5	2.5	2.5	1	1	2.5	2.5
WLVSA72	924.5	0	0	0	0	2.5	0	0	0	3.5	2.5
WRSA284	923.0	0	0	0	0	0	0	0	0	0	0
WRSA289	922.0	0	0	0	0	0	0	0	0	5	4.5
WRSA294	919.5	0	0	0	0	3	0	4.5	4	4	3
WRSA299	911.0	2.5	1.5	1	1.5	2	2.5	1	0.5	1	1.5
WRSA300	908.0	1.5	0.5	0.5	0.5	0.5	1.5	0.5	0	0.5	0.5
WRSA302	912.0	0	4	3.5	3.5	3.5	0	2	1.5	2	2
WRSA304	911.5	2.5	1.5	1.5	1.5	2	3	1	1	1	1.5
WRSA305A	910.5	2	1	1	1	1.5	2.5	1	0.5	1	1.5
WRSA305B	908.5	1.5	0.5	0.5	0.5	1	1.5	0.5	0.5	0.5	1
WRSA305C	906.0	0.5	0	0	0	0	1	0	0	0	0
WRSA305D	913.0	3.5	2	1.5	2	2	3.5	1.5	1	1.5	2
WRSA306	910.0	4	2.5	2	2.5	2.5	4.5	1.5	1	1.5	1.5
WRSA307	910.0	0	3	2.5	3	2.5	0	1.5	1.5	1.5	1
WRSA309	914.0	0	2.5	2	2.5	2.5	0	2	1.5	2	2.5
WRSA311	907.0	2	1	1	1	1.5	2	0.5	0.5	0.5	1

- continued -

Appendix Table C3. Continued												
Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated										
		Existing Conditions						With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
WRSA312	905.0	1.5	1	0.5	1	0.5		1.5	0.5	0	0.5	0.5
WRSA314	912.5	0	3.5	3	3	3.5		0	1.5	1.5	1.5	2
WRSA315	910.5	0	0	4	4	4		3	1	0.5	1	1.5
WRSA316	910.5	3.5	2	2	2	2.5		3	1	0.5	1	1.5
WRSA317A	908.0	2.5	1.5	1	1.5	1.5		3	1	0.5	1	1.5
WRSA317B	906.0	4	2	2	2	2		4	1	1	1	0.5
WRSA350	910.0	4	2.5	2	2	2.5		4	1.5	1	1.5	2
WRSA351	908.0	2.5	1.5	1	1.5	1.5		2.5	1	0.5	1	1.5
WRSA352	910.5	0	2.5	2	2.5	2.5		0	2	1.5	2	2.5
WRSA353	917.0	0	0	3	3.5	3.5		0	3	2.5	3	3
WRSA354	918.0	0	2.5	2	2	2.5		0	2	2	2	2.5
WRSA355	914.5	2	1	0.5	1	1		2	1	0.5	1	1
WRSA356	917.5	2.5	1	1	1	1.5		2.5	1	1	1	1.5
WRSA357	919.0	3	1.5	1	1.5	1.5		3	1.5	1	1	1.5
WRSA358	921.0	0	2	1.5	1.5	2		0	2	1.5	1.5	2
WRSA361	907.0	2	1	1	1	1.5		2	0.5	0	0.5	1
WRSA363	911.0	0	2.5	2	2	2.5		0	2	1.5	1.5	2
WRSA364	912.0	0	2.5	2	2	2.5		0	2	1.5	2	2.5
WRSA373	927.5	0	0	0	0	0		0	0	0	0	0
WRSA378	926.0	0	0	0	0	4.5		0	0	0	0	4.5
WRSA383	923.5	0	0	0	0	0		0	0	0	0	0
WRSA384	925.0	0	0	0	0	4.5		0	0	0	0	4.5
WRSA389	921.5	0	0	3	3	3		0	0	3	3	3
WRSA390	913.0	2	1	0.5	1	1.5		2	1	0.5	1	1.5
WRSA907	913.0	3	2	1.5	1.5	2		3	1.5	1.5	1.5	2

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C4. Time from Activation of Staging Area to When Flood Water Leaves, by Storage Area, by Flood Event Frequency for With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
CHRSA01	915.0	0	0	0	0	9		0	10.5	11.5	14	14
CHRSA02	914.5	0	0	0	6.5	13.5		0	12	13.5	15.5	16
CHRSA03	919.5	0	0	0	0	0		0	7	9	11	11.5
CHRSA04	918.0	0	0	0	0	10.5		0	10.5	12	14	14.5
CHRSA05	921.0	0	0	0	0	10		0	0	7.5	9.5	11
CHRSA06	921.5	0	0	0	0	9.5		0	0	7	8.5	10.5
CHRSA07	913.0	0	7.5	9.5	10.5	14.5		0	12.5	13.5	16.5	16.5
CHRSA08	918.5	0	0	0	5.5	10		0	8.5	10	11.5	12.5
CHRSA09	922.5	0	0	0	2	9.5		0	0	0	7.5	10
CHRSA10	920.5	0	0	0	0	8.5		0	0	8	9.5	11
CHRSA11	924.5	0	0	0	0	8.5		0	0	0	0	8.5
CHRSA12	924.5	0	0	0	0	8		0	0	0	0	9
CHRSA13	915.0	0	7.5	9.5	10.5	15		0	11.5	13	15.5	17
CHRSA14	924.0	0	0	0	0	8.5		0	0	0	0	9
CHRSA15	919.0	0	0	6.5	7.5	11.5		0	8.5	10	12	13.5
CHRSA16	917.0	0	6	8	9	13		0	10	11.5	14	15.5
CHRSA17	919.5	0	5	7	8	11.5		0	8.5	10	12	13.5
WLVSA27	911.0	0	0	8	9.5	12.5		0	13	14	16.5	16
WLVSA28	913.0	0	0	0	7	10.5		0	11.5	12.5	15	15
WLVSA29	913.0	0	0	0	7	10.5		0	11.5	12.5	15	15
WLVSA30	915.5	0	0	0	0	0		0	10.5	12	14	14.5
WLVSA31	919.0	0	0	0	0	0		0	7.5	9.5	11.5	12
WLVSA32	919.5	0	0	0	0	0		0	7	9	12	13
WLVSA33	915.0	0	0	0	0	6.5		0	11	12.5	14.5	15
WLVSA34	913.0	0	0	6.5	8	11		0	11.5	12.5	15	15
WLVSA34a	915.0	0	0	0	0	6.5		0	10.5	12	14	14.5
WLVSA35	905.0	8	11	12.5	15	21		8	15.5	16	18.5	20.5
WLVSA36	909.0	5.5	9	10.5	12	16.5		5.5	14.5	15	18	18
WLVSA37	910.0	5.5	7.5	9.5	10.5	14.5		5.5	13.5	14.5	17	16.5
WLVSA38	912.0	5.5	5	7.5	9	12		5.5	12.5	13.5	16	16
WLVSA39	918.5	0	0	0	0	0		0	8.5	10	12	12.5
WLVSA40	918.5	0	0	0	0	0		0	9	11	13	13.5
WLVSA41	921.0	0	0	0	0	0		0	0	0	11	12
WLVSA42	921.0	0	0	0	0	0		0	0	0	10	10.5
WLVSA42a	922.0	0	0	0	0	0		0	0	0	8.5	9.5
WLVSA43	921.0	0	0	0	0	0		0	0	6.5	9.5	10.5

- continued -

Appendix Table C4. Continued												
Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
WLVSA44	922.0	0	0	0	0	0		0	0	0	8	9
WLVSA45	913.0	5.5	5	6.5	8.5	11		5.5	11.5	13	15.5	15.5
WLVSA46	913.0	0	0	8	9	12.5		0	12	13	15.5	16
WLVSA47	913.0	0	6.5	9	10	13.5		0	12	13.5	16	16.5
WLVSA48	920.0	0	0	0	0	6.5		0	0	8.5	10	11
WLVSA49	920.0	0	0	0	0	7		0	0	8.5	10.5	11
WLVSA50	922.0	0	0	0	0	6.5		0	0	0	8.5	9.5
WLVSA51	923.5	0	0	0	0	0		0	0	0	0	7
WLVSA51a	923.0	0	0	0	0	0		0	0	0	0	8
WLVSA53	922.0	0	0	0	6	7		0	0	4	8.5	9.5
WLVSA54	921.5	0	0	0	0	7		0	0	6	9	10.5
WLVSA55	921.0	0	0	0	0	7		0	0	7	9	10.5
WLVSA56	915.0	0	5.5	7.5	8.5	12		0	11	12	14.5	15
WLVSA57	921.0	0	0	0	5	11		0	0	7.5	9	12.5
WLVSA58	921.0	0	0	0	5	11.5		0	0	7.5	9	12.5
WLVSA59	922.0	0	0	0	5.5	12		0	0	7	8.5	13.5
WLVSA63	922.0	0	0	0	5.5	10		0	0	7	8.5	11.5
WLVSA64	922.0	0	0	0	5	10		0	0	7	8.5	11.5
WLVSA65	919.0	0	0	6.5	7.5	11		0	8.5	10	12	13
WLVSA66	923.5	0	0	0	5.5	9.5		0	0	6	7.5	10.5
WLVSA67	921.5	5	4.5	5.5	8	10		5	4.5	7.5	10	11.5
WLVSA72	924.5	0	0	0	0	8.5		0	0	0	5.5	9.5
WRSA284	923.0	0	0	0	0	0		0	0	0	0	0
WRSA289	922.0	0	0	0	0	0		0	0	0	7	8.5
WRSA294	919.5	0	0	0	0	7.5		0	6	8	9.5	10.5
WRSA299	911.0	7.5	10.5	12	14.5	19.5		7.5	12.5	14	16.5	18.5
WRSA300	908.0	9.5	12.5	14.5	18	26.5		9	13.5	15	18	24
WRSA302	912.0	0	7	9	10.5	14		0	12.5	13.5	16	16
WRSA304	911.5	7.5	10	11.5	14	19		7	12.5	13.5	16	18
WRSA305A	910.5	8	10.5	12.5	15	20.5		7.5	12.5	14	16	19
WRSA305B	908.5	9	12	14	17	25		9	13	15	17.5	22.5
WRSA305C	906.0	10.5	14.5	17	22	33		10.5	15.5	17	21.5	32
WRSA305D	913.0	6	9	10	12.5	16.5		5.5	12	13	15.5	16.5
WRSA306	910.0	6	10.5	12	14	18		6.5	14.5	15.5	18.5	19
WRSA307	910.0	0	9	10.5	12.5	16.5		0	14	15	17.5	17.5
WRSA309	914.0	0	8	9	11.5	15		0	11.5	12.5	15	16
WRSA311	907.0	8.5	11.5	13.5	16	22.5		8.5	15.5	16.5	19	20
- continued -												

Appendix Table C4. Continued												
Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
		10-yr	25-yr	50-yr	100-yr	500-yr		10-yr	25-yr	50-yr	100-yr	500-yr
WRSA312	905.0	9.5	13	15	18	27		9.5	15.5	16.5	19	24
WRSA314	912.5	0	5.5	7.5	10	13		0	11.5	13	15	16
WRSA315	910.5	0	0	9	11.5	14.5		6.5	12	13	15.5	16
WRSA316	910.5	6.5	10.5	12	14.5	18.5		6.5	12	13	15.5	16.5
WRSA317A	908.0	8	11.5	13	15.5	20		8	15.5	16.5	19	20
WRSA317B	906.0	7	10	12	14	19.5		7.5	15	15.5	18.5	19
WRSA350	910.0	6.5	10.5	12	14	18		6.5	14.5	16	18.5	19
WRSA351	908.0	8	11.5	13	15	20		8	15	16.5	19	19.5
WRSA352	910.5	0	10.5	12	14	18		0	14.5	16	18.5	19
WRSA353	917.0	0	0	5	8	11		0	9	10	12.5	13
WRSA354	918.0	0	7	8	10	14		0	9	10	12.5	15
WRSA355	914.5	7.5	10	11.5	14.5	19.5		7.5	12	13.5	16	19.5
WRSA356	917.5	6.5	9	10	13	17.5		6.5	10	12	14.5	17.5
WRSA357	919.0	5.5	8	9	11.5	15.5		5.5	9	10.5	13	16
WRSA358	921.0	0	6.5	7.5	9.5	13		0	7.5	8.5	10.5	13.5
WRSA361	907.0	8.5	11.5	13.5	16	22.5		8.5	15	16.5	19	20
WRSA363	911.0	0	10.5	11.5	13.5	17.5		0	14.5	15.5	18	18.5
WRSA364	912.0	0	10	11.5	13.5	17		0	14	15	17.5	18
WRSA373	927.5	0	0	0	0	0		0	0	0	0	0
WRSA378	926.0	0	0	0	0	8		0	0	0	0	8.5
WRSA383	923.5	0	0	0	0	0		0	0	0	0	0
WRSA384	925.0	0	0	0	0	9		0	0	0	0	9
WRSA389	921.5	0	0	6	8	11		0	0	7.5	9.5	11.5
WRSA390	913.0	7.5	10.5	12	15	20.5		7.5	12	13.5	16	20
WRSA907	913.0	6	9	10.5	12.5	17		6	12	13.5	16	17

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C5. Acreage of Storage Areas That Do Not Flood in Either the With or Without Diversion Conditions, by Storage Area, by Flood Event Frequency (Hydrology Group One)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
CHRSA01	915.0	307				
CHRSA02	914.5	305				
CHRSA03	919.5	304				
CHRSA04	918.0	284				
CHRSA05	921.0	320	320			
CHRSA06	921.5	117	117			
CHRSA07	913.0	151				
CHRSA08	918.5	161				
CHRSA09	922.5	301	301	301		
CHRSA10	920.5	326	326			
CHRSA11	924.5	305	305	305	305	
CHRSA12	924.5	327	327	327	327	
CHRSA13	915.0	629				
CHRSA14	924.0	317	317	317	317	
CHRSA15	919.0	324				
CHRSA16	917.0	629				
CHRSA17	919.5	839				
WLVSA27	911.0	430				
WLVSA28	913.0	290				
WLVSA29	913.0	935				
WLVSA30	915.5	629				
WLVSA31	919.0	1,266				
WLVSA32	919.5	1,270				
WLVSA33	915.0	631				
WLVSA34	913.0	326				
WLVSA34a	915.0	627				
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5	469				
WLVSA40	918.5	633				
WLVSA41	921.0	1,466	1,466	1,466		
WLVSA42	921.0	631	631	631		
WLVSA42a	922.0	644	644	644		
WLVSA43	921.0	635	635			
- continued -						

Appendix Table C5. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WLVSA44	922.0	179	179	179		
WLVSA45	913.0					
WLVSA46	913.0	630				
WLVSA47	913.0	625				
WLVSA48	920.0	308	308			
WLVSA49	920.0	328	328			
WLVSA50	922.0	630	630	630		
WLVSA51	923.5	634	634	634	634	
WLVSA51a	923.0	642	642	642	642	
WLVSA53	922.0	638	638			
WLVSA54	921.5	334	334			
WLVSA55	921.0	302	302			
WLVSA56	915.0	629				
WLVSA57	921.0	210	210			
WLVSA58	921.0	173	173			
WLVSA59	922.0	227	227			
WLVSA63	922.0	228	228			
WLVSA64	922.0	400	400			
WLVSA65	919.0	127				
WLVSA66	923.5	212	212			
WLVSA67	921.5					
WLVSA72	924.5	593	593	593		
WRSA284	923.0	597	597	597	597	597
WRSA289	922.0	629	629	629		
WRSA294	919.5	625				
WRSA299	911.0					
WRSA300	908.0					
WRSA302	912.0	404				
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0					
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0	254				
WRSA309	914.0	636				
WRSA311	907.0					
- continued -						

Appendix Table C5. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------ acres ----------------------------				
WRSA312	905.0					
WRSA314	912.5	619				
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5	297				
WRSA353	917.0	292				
WRSA354	918.0	295				
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0	492				
WRSA361	907.0					
WRSA363	911.0	268				
WRSA364	912.0	252				
WRSA373	927.5	632	632	632	632	632
WRSA378	926.0	156	156	156	156	
WRSA383	923.5	153	153	153	153	153
WRSA384	925.0	155	155	155	155	
WRSA389	921.5	151	151			
WRSA390	913.0					
WRSA907	913.0					
Totals		31,784	13,900	8,991	3,918	1,382

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C6. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is the Same Duration With and Without Diversion Conditions, by Storage Area, by Flood Event Frequency (Hydrology Group Two)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0					
CHRSA08	918.5					
CHRSA09	922.5					301
CHRSA10	920.5					
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0					
WLVSA34a	915.0					
WLVSA35	905.0	409				
WLVSA36	909.0	374				
WLVSA37	910.0	249				
WLVSA38	912.0	222				
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C6. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		acres				
WLVSA44	922.0					
WLVSA45	913.0	309				
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0					
WLVSA54	921.5					
WLVSA55	921.0					
WLVSA56	915.0					
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0					
WLVSA66	923.5					
WLVSA67	921.5	726				
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					
WRSA299	911.0	627				
WRSA300	908.0				626	
WRSA302	912.0					
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5	408				
WRSA305C	906.0			808		
WRSA305D	913.0					432
WRSA306	910.0	619				
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0	305				
- continued -						

Appendix Table C6. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WRSA312	905.0	631				
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					353
WRSA317B	906.0					
WRSA350	910.0	274				
WRSA351	908.0	309				
WRSA352	910.5					
WRSA353	917.0					
WRSA354	918.0					
WRSA355	914.5	415				415
WRSA356	917.5	622				622
WRSA357	919.0	614				
WRSA358	921.0					
WRSA361	907.0	192				
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					155
WRSA389	921.5					
WRSA390	913.0	269				
WRSA907	913.0	394				394
Totals		7,968	0	808	626	2,672

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C7. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is Longer With the Diversion, by Storage Area, by Flood Event Frequency (Hydrology Group Three)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
CHRSA01	915.0					307
CHRSA02	914.5				305	305
CHRSA03	919.5					
CHRSA04	918.0					284
CHRSA05	921.0					320
CHRSA06	921.5					117
CHRSA07	913.0		151	151	151	151
CHRSA08	918.5				161	161
CHRSA09	922.5				301	
CHRSA10	920.5					326
CHRSA11	924.5					
CHRSA12	924.5					327
CHRSA13	915.0		629	629	629	629
CHRSA14	924.0					317
CHRSA15	919.0			324	324	324
CHRSA16	917.0		629	629	629	629
CHRSA17	919.5		839	839	839	839
WLVSA27	911.0			430	430	430
WLVSA28	913.0				290	290
WLVSA29	913.0				935	935
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					631
WLVSA34	913.0			326	326	326
WLVSA34a	915.0					627
WLVSA35	905.0		409	409	409	409
WLVSA36	909.0		374	374	374	374
WLVSA37	910.0		249	249	249	249
WLVSA38	912.0		222	222	222	222
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C7. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WLVSA44	922.0					
WLVSA45	913.0		309	309	309	309
WLVSA46	913.0			630	630	630
WLVSA47	913.0		625	625	625	625
WLVSA48	920.0					308
WLVSA49	920.0					328
WLVSA50	922.0					630
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0				638	638
WLVSA54	921.5					334
WLVSA55	921.0					302
WLVSA56	915.0		629	629	629	629
WLVSA57	921.0				210	210
WLVSA58	921.0				173	173
WLVSA59	922.0				227	227
WLVSA63	922.0				228	228
WLVSA64	922.0				400	400
WLVSA65	919.0			127	127	127
WLVSA66	923.5				212	212
WLVSA67	921.5		726	726	726	726
WLVSA72	924.5					593
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					625
WRSA299	911.0		627	627	627	
WRSA300	908.0		626	626		
WRSA302	912.0		404	404	404	404
WRSA304	911.5		635	635	635	
WRSA305A	910.5		225	225	225	
WRSA305B	908.5		408	408	408	
WRSA305C	906.0		808			
WRSA305D	913.0		432	432	432	
WRSA306	910.0		619	619	619	619
WRSA307	910.0		254	254	254	254
WRSA309	914.0		636	636	636	636
WRSA311	907.0		305	305	305	
- continued -						

Appendix Table C7. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WRSA312	905.0		631	631	631	
WRSA314	912.5		619	619	619	619
WRSA315	910.5			613	613	613
WRSA316	910.5	611	611	611	611	
WRSA317A	908.0		353	353	353	
WRSA317B	906.0	230	230	230	230	230
WRSA350	910.0		274	274	274	274
WRSA351	908.0		309	309	309	
WRSA352	910.5		297	297	297	297
WRSA353	917.0			292	292	292
WRSA354	918.0		295	295	295	295
WRSA355	914.5		415	415	415	
WRSA356	917.5		622	622	622	
WRSA357	919.0		614	614	614	614
WRSA358	921.0		492	492	492	492
WRSA361	907.0		192	192	192	
WRSA363	911.0		268	268	268	268
WRSA364	912.0		252	252	252	252
WRSA373	927.5					
WRSA378	926.0					156
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5			151	151	151
WRSA390	913.0		269	269	269	
WRSA907	913.0		394	394	394	
Totals		841	18,907	20,992	24,446	24,249

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C8. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is Shorter With the Diversion, by Storage Area, by Flood Event Frequency (Hydrology Group Four)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0					
CHRSA08	918.5					
CHRSA09	922.5					
CHRSA10	920.5					
CHRSA11	924.5					305
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0					
WLVSA34a	915.0					
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C8. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WLVSA44	922.0					
WLVSA45	913.0					
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0					
WLVSA54	921.5					
WLVSA55	921.0					
WLVSA56	915.0					
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0					
WLVSA66	923.5					
WLVSA67	921.5					
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					
WRSA299	911.0					627
WRSA300	908.0	626				626
WRSA302	912.0					
WRSA304	911.5	635				635
WRSA305A	910.5	225				225
WRSA305B	908.5					408
WRSA305C	906.0	808			808	808
WRSA305D	913.0	432				
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0					305
- continued -						

Appendix Table C8. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WRSA312	905.0					631
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					611
WRSA317A	908.0	353				
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					309
WRSA352	910.5					
WRSA353	917.0					
WRSA354	918.0					
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0					192
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5					
WRSA390	913.0					269
WRSA907	913.0					
Totals		3,079	0	0	808	5,951

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C9. Acreage of Storage Areas That Flood With the Diversion but Would Not Flood With Existing Conditions, by Storage Area, by Flood Event Frequency (Hydrology Group Five)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
CHRSA01	915.0		307	307	307	
CHRSA02	914.5		305	305		
CHRSA03	919.5		304	304	304	304
CHRSA04	918.0		284	284	284	
CHRSA05	921.0			320	320	
CHRSA06	921.5			117	117	
CHRSA07	913.0					
CHRSA08	918.5		161	161		
CHRSA09	922.5					
CHRSA10	920.5			326	326	
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0		324			
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0		430			
WLVSA28	913.0		290	290		
WLVSA29	913.0		935	935		
WLVSA30	915.5		629	629	629	629
WLVSA31	919.0		1266	1266	1266	1266
WLVSA32	919.5		1270	1270	1270	1270
WLVSA33	915.0		631	631	631	
WLVSA34	913.0		326			
WLVSA34a	915.0		627	627	627	
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5		469	469	469	469
WLVSA40	918.5		633	633	633	633
WLVSA41	921.0				1466	1466
WLVSA42	921.0				631	631
WLVSA42a	922.0				644	644
WLVSA43	921.0			635	635	635
- continued -						

Appendix Table C9. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WLVSA44	922.0				179	179
WLVSA45	913.0					
WLVSA46	913.0		630			
WLVSA47	913.0					
WLVSA48	920.0			308	308	
WLVSA49	920.0			328	328	
WLVSA50	922.0				630	
WLVSA51	923.5					634
WLVSA51a	923.0					642
WLVSA53	922.0			638		
WLVSA54	921.5			334	334	
WLVSA55	921.0			302	302	
WLVSA56	915.0					
WLVSA57	921.0			210		
WLVSA58	921.0			173		
WLVSA59	922.0			227		
WLVSA63	922.0			228		
WLVSA64	922.0			400		
WLVSA65	919.0		127			
WLVSA66	923.5			212		
WLVSA67	921.5					
WLVSA72	924.5				593	
WRSA284	923.0					
WRSA289	922.0				629	629
WRSA294	919.5		625	625	625	
WRSA299	911.0					
WRSA300	908.0					
WRSA302	912.0					
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0					
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0					
- continued -						

Appendix Table C9. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
		10-yr	25-yr	50-yr	100-yr	500-yr
		------------------------- acres -----------------------------				
WRSA312	905.0					
WRSA314	912.5					
WRSA315	910.5	613	613			
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5					
WRSA353	917.0		292			
WRSA354	918.0					
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0					
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5					
WRSA390	913.0					
WRSA907	913.0					
Totals		613	11,478	13,494	14,487	10,031

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C10. Inundated Acres, With FM Diversion Staging Area							
Storage Area	Approx. Field Elevation[a]		Flood Event Size				
		Size	10-yr	25-yr	50-yr	100-yr	500-yr
		---------------------------------- acres --------------------------------------					
CHRSA01	915.0	306.7	0.0	233.8	304.8	306.1	306.2
CHRSA02	914.5	305.0	0.0	304.9	305.0	305.0	305.0
CHRSA03	919.5	304.2	0.0	50.0	206.1	285.2	297.1
CHRSA04	918.0	283.6	0.0	105.2	251.8	279.1	283.1
CHRSA05	921.0	320.4	0.0	15.8	48.4	85.0	318.6
CHRSA06	921.5	116.6	0.0	3.2	36.4	71.9	105.0
CHRSA07	913.0	150.5	0.0	46.4	87.3	139.1	150.5
CHRSA08	918.5	160.5	0.0	20.0	38.1	59.1	127.0
CHRSA09	922.5	301.1	0.0	0.0	3.1	8.0	298.6
CHRSA10	920.5	326.5	0.0	0.4	6.1	12.8	101.7
CHRSA11	924.5	304.7	0.0	0.0	0.7	4.0	302.6
CHRSA12	924.5	326.9	0.0	0.0	0.2	6.0	251.7
CHRSA13	915.0	628.8	9.4	61.9	114.3	166.5	508.0
CHRSA14	924.0	310.3	0.0	0.0	2.4	7.4	308.0
CHRSA15	919.0	323.7	0.0	19.1	39.3	75.9	260.3
CHRSA16	917.0	629.0	0.0	50.7	89.7	125.8	298.1
CHRSA17	919.5	838.7	0.0	51.4	123.4	222.6	526.4
WLVSA27S	911.0	201.2	0.0	201.2	201.2	201.2	201.2
WLVSA28S	913.0	124.5	0.0	124.3	124.4	124.4	124.5
WLVSA29S	913.0	389.5	0.0	388.6	389.4	389.5	389.5
WLVSA30S	915.5	258.8	0.0	253.1	258.3	258.6	258.7
WLVSA31S	919.0	510.2	0.0	80.5	167.0	270.5	300.4
WLVSA32	919.5	1,269.8	0.0	24.5	314.4	643.3	719.2
WLVSA33	915.0	631.1	0.0	597.1	624.4	630.0	630.6
WLVSA34	913.0	325.5	0.0	228.2	314.3	321.3	324.4
WLVSA34a	915.0	627.1	0.0	552.2	626.2	627.0	627.1
WLVSA35	905.0	409.2	26.9	409.2	409.2	409.2	409.2
WLVSA36	909.0	373.8	0.8	373.6	373.8	373.8	373.8
WLVSA37	910.0	249.4	24.5	248.4	249.2	249.4	249.4
WLVSA38	912.0	221.6	62.9	221.1	221.5	221.6	221.6
WLVSA39	918.5	469.3	0.0	110.9	348.1	422.4	454.7
WLVSA40	918.5	633.0	0.0	302.7	521.2	575.3	599.9
WLVSA41	921.0	1,466.5	0.0	12.3	114.6	529.3	653.6
WLVSA42	921.0	630.6	0.6	5.7	46.7	235.8	340.5
WLVSA42a	922.0	644.3	0.0	2.1	3.7	22.3	82.3
WLVSA43	921.0	635.1	3.0	6.5	18.7	106.3	272.2
- continued							

Appendix Table C10. Continued							
	Approx.		Flood Event Size				
	Field	Size	10-yr	25-yr	50-yr	100-yr	500-yr
Storage Area	Elevation[a]	---------------------------------- acres -------------------------------------					
WLVSA44	922.0	178.8	2.2	3.7	4.5	9.9	19.6
WLVSA45	913.0	309.2	37.6	266.0	297.3	305.1	307.0
WLVSA46	913.0	629.4	0.0	562.5	619.5	625.3	627.1
WLVSA47	913.0	625.5	0.0	357.1	502.4	611.7	624.6
WLVSA48	920.0	308.4	0.0	2.4	35.6	234.5	293.7
WLVSA49	920.0	327.9	0.0	0.5	43.2	243.0	293.2
WLVSA50	922.0	630.2	7.2	8.2	9.8	23.9	128.2
WLVSA51	923.5	634.2	6.2	7.4	8.9	51.3	146.0
WLVSA51a	923.0	641.6	5.0	5.9	7.1	12.6	27.7
WLVSA53	922.0	637.7	1.7	4.0	11.1	43.9	78.2
WLVSA54	921.5	334.0	3.3	5.7	12.2	65.4	277.1
WLVSA55	921.0	301.7	0.0	1.1	35.9	151.6	295.9
WLVSA56	915.0	629.0	0.0	113.7	353.9	609.0	628.1
WLVSA57	921.0	210.4	0.0	0.1	48.1	166.1	209.6
WLVSA58	921.0	173.3	0.0	0.1	20.3	94.6	170.5
WLVSA59	922.0	227.3	0.0	0.0	5.8	92.1	226.9
WLVSA63	922.0	228.0	1.1	1.6	67.5	181.6	221.6
WLVSA64	922.0	400.2	0.4	1.4	147.4	394.1	400.0
WLVSA65	919.0	127.0	0.0	6.5	34.6	124.7	127.0
WLVSA66	923.5	212.3	0.2	0.4	43.8	178.5	210.1
WLVSA67	921.5	726.1	15.8	18.2	20.4	58.9	166.8
WLVSA72	924.5	593.2	0.0	0.0	0.0	3.2	70.3
WRSA284	923.0	597.4	0.4	1.1	2.5	6.0	9.2
WRSA289	922.0	629.3	4.5	7.7	10.0	14.4	18.0
WRSA294	919.5	625.3	0.0	7.1	20.4	54.1	89.2
WRSA299	911.0	626.9	13.3	180.4	344.9	520.3	572.1
WRSA300	908.0	626.3	110.6	620.2	625.3	626.0	626.0
WRSA302	912.0	241.4	0.0	240.6	240.8	240.9	240.9
WRSA304	911.5	634.8	12.5	435.1	616.2	634.2	634.4
WRSA305A	910.5	225.0	125.3	225.0	225.0	225.0	225.0
WRSA305B	908.5	407.9	293.2	407.9	407.9	407.9	407.9
WRSA305C	906.0	808.3	382.8	808.3	808.3	808.3	808.3
WRSA305D	913.0	431.6	356.8	431.6	431.6	431.6	431.6
WRSA306	910.0	502.4	73.1	502.4	502.4	502.4	502.4
WRSA307	910.0	213.8	0.0	213.8	213.8	213.8	213.8
WRSA309	914.0	635.5	3.6	631.5	635.2	635.4	635.5
- continued -							

Appendix Table C10. Continued							
	Approx. Field Elevation[a]		Flood Event Size				
Storage Area		Size	10-yr	25-yr	50-yr	100-yr	500-yr
		---------------------------------- acres --------------------------------------					
WRSA311	907.0	305.2	155.9	305.2	305.2	305.2	305.2
WRSA312	905.0	631.3	194.6	631.3	631.3	631.3	631.3
DIVSA86	912.5	575.9	0.5	575.7	575.9	575.9	575.9
DIVSA87	910.5	520.1	172.3	520.1	520.1	520.1	520.1
DIVSA88	910.5	517.6	247.5	517.6	517.6	517.6	517.6
DIVSA89	908.0	298.2	142.0	298.2	298.2	298.2	298.2
DIVSA90	906.0	216.0	12.3	216.0	216.0	216.0	216.0
WRSA350	910.0	274.3	6.4	274.3	274.3	274.3	274.3
WRSA351	908.0	308.7	43.4	308.7	308.7	308.7	308.7
WRSA352	910.5	296.9	0.0	296.2	296.5	296.6	296.7
WRSA353	917.0	291.9	0.0	166.9	284.5	290.5	290.8
WRSA354	918.0	295.3	2.8	56.9	200.1	285.8	293.1
WRSA355	914.5	415.4	20.4	139.4	261.5	378.4	411.5
WRSA356	917.5	622.2	16.8	52.9	143.2	572.5	619.1
WRSA357	919.0	614.4	16.0	59.9	98.0	447.5	606.0
WRSA358	921.0	491.6	0.7	86.7	123.4	317.5	435.9
WRSA361	907.0	192.2	89.3	192.2	192.2	192.2	192.2
WRSA363	911.0	268.2	0.1	268.2	268.2	268.2	268.2
WRSA364	912.0	251.8	0.1	251.3	251.8	251.8	251.8
WRSA373	927.5	631.8	0.0	0.0	0.0	0.1	1.0
WRSA378	926.0	156.1	0.0	0.0	0.0	0.3	7.7
WRSA383	923.5	152.7	0.0	0.0	0.0	0.0	0.1
WRSA384	925.0	155.0	0.0	0.0	0.0	0.3	35.0
WRSA389	921.5	150.7	0.0	0.0	0.1	0.9	3.6
WRSA390	913.0	268.9	5.3	26.0	48.0	103.2	138.6
WRSA907	913.0	393.9	1.2	219.2	301.8	381.0	386.8
Totals		41,595.2	2,712.5	16,647.2	20,513.4	25,806.1	30,829.5

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C11. Inundated Acres, With Current Conditions							
	Approx.		Flood Event Size				
Storage Area	Field Elevation[a]	Size	10-yr	25-yr	50-yr	100-yr	500-yr
		---------------------------------- acres --------------------------------------					
CHRSA01	915.0	306.7	0.0	0.0	0.0	1.6	142.8
CHRSA02	914.5	305.0	0.0	0.0	3.9	15.1	305.0
CHRSA03	919.5	304.2	0.0	0.0	0.0	0.0	3.8
CHRSA04	918.0	283.6	0.0	0.0	0.0	0.7	138.7
CHRSA05	921.0	320.4	0.0	0.0	0.0	0.0	318.7
CHRSA06	921.5	116.6	0.0	0.0	0.0	1.5	93.1
CHRSA07	913.0	150.5	0.0	11.9	26.7	37.0	147.2
CHRSA08	918.5	160.5	0.0	0.4	4.5	11.5	100.3
CHRSA09	922.5	301.1	0.0	0.0	0.0	0.0	298.7
CHRSA10	920.5	326.5	0.0	0.0	0.0	0.0	65.4
CHRSA11	924.5	304.7	0.0	0.0	0.0	0.0	302.6
CHRSA12	924.5	326.9	0.0	0.0	0.0	0.1	243.8
CHRSA13	915.0	628.8	9.3	32.4	60.3	106.9	502.1
CHRSA14	924.0	310.3	0.0	0.0	0.0	0.0	308.1
CHRSA15	919.0	323.7	0.0	3.8	18.4	36.3	257.5
CHRSA16	917.0	629.0	0.0	20.5	49.2	85.0	291.0
CHRSA17	919.5	838.7	0.0	15.6	68.4	147.0	520.2
WLVSA27S	911.0	201.2	0.0	6.0	47.7	131.7	170.3
WLVSA28S	913.0	124.5	0.0	0.0	0.2	3.8	13.2
WLVSA29S	913.0	389.5	0.0	0.0	0.1	8.6	31.9
WLVSA30S	915.5	258.8	0.0	0.0	0.0	0.0	0.3
WLVSA31S	919.0	510.2	0.0	0.0	0.0	0.0	0.0
WLVSA32	919.5	1,269.8	0.0	0.0	0.0	0.0	0.0
WLVSA33	915.0	631.1	0.0	0.0	0.1	0.5	1.5
WLVSA34	913.0	325.5	0.0	0.3	1.1	2.1	6.8
WLVSA34a	915.0	627.1	0.0	0.0	0.8	1.6	2.6
WLVSA35	905.0	409.2	25.4	77.1	133.9	173.6	271.3
WLVSA36	909.0	373.8	0.6	28.7	74.4	122.8	280.6
WLVSA37	910.0	249.4	24.5	31.8	65.0	86.9	121.9
WLVSA38	912.0	221.6	63.0	77.1	100.8	126.8	144.4
WLVSA39	918.5	469.3	0.0	0.0	0.0	0.1	0.7
WLVSA40	918.5	633.0	0.0	0.0	0.0	0.0	0.9
WLVSA41	921.0	1,466.5	0.0	0.0	0.0	0.0	0.0
WLVSA42	921.0	630.6	0.6	0.9	1.1	1.7	2.3
WLVSA42a	922.0	644.3	0.0	0.0	0.0	0.7	1.0
WLVSA43	921.0	635.1	3.0	3.3	3.4	3.8	4.2
- continued -							

Appendix Table C11 Continued							
Storage Area	Approx. Field Elevation[a]	Size	Flood Event Size				
			10-yr	25-yr	50-yr	100-yr	500-yr
		--------------------------------- acres -------------------------------------					
WLVSA44	922.0	178.8	2.2	2.4	2.4	2.7	3.0
WLVSA45	913.0	309.2	37.6	42.8	47.9	61.8	77.2
WLVSA46	913.0	629.4	0.0	0.1	24.9	43.8	94.8
WLVSA47	913.0	625.5	0.0	10.7	34.1	48.1	431.6
WLVSA48	920.0	308.4	0.0	0.0	0.0	0.0	4.9
WLVSA49	920.0	327.9	0.0	0.0	0.2	1.4	5.3
WLVSA50	922.0	630.2	7.2	7.6	8.2	9.8	13.6
WLVSA51	923.5	634.2	6.2	6.6	7.4	8.9	16.3
WLVSA51a	923.0	641.6	5.0	5.4	6.0	7.2	9.1
WLVSA53	922.0	637.7	1.7	2.5	6.4	24.6	38.5
WLVSA54	921.5	334.0	3.3	4.5	6.4	11.1	33.2
WLVSA55	921.0	301.7	0.0	0.0	0.0	0.0	79.1
WLVSA56	915.0	629.0	0.0	1.1	18.7	43.5	354.0
WLVSA57	921.0	210.4	0.0	0.0	0.0	3.9	209.5
WLVSA58	921.0	173.3	0.0	0.0	0.0	2.5	170.3
WLVSA59	922.0	227.3	0.0	0.0	0.0	3.3	226.8
WLVSA63	922.0	228.0	1.1	1.5	1.6	19.3	221.6
WLVSA64	922.0	400.2	0.4	0.4	1.1	32.5	400.0
WLVSA65	919.0	127.0	0.0	0.0	6.0	25.8	127.0
WLVSA66	923.5	212.3	0.2	0.4	1.2	110.3	209.9
WLVSA67	921.5	726.1	15.8	17.2	19.2	32.3	160.5
WLVSA72	924.5	593.2	0.0	0.0	0.0	0.2	67.5
WRSA284	923.0	597.4	0.4	0.8	1.1	1.6	3.1
WRSA289	922.0	629.3	4.5	6.5	7.3	8.7	11.0
WRSA294	919.5	625.3	0.0	1.7	2.4	4.3	28.5
WRSA299	911.0	626.9	14.2	24.3	32.5	41.1	51.7
WRSA300	908.0	626.3	121.1	220.8	266.0	309.8	358.1
WRSA302	912.0	404.0	0.5	16.1	28.8	42.4	398.0
WRSA304	911.5	634.8	14.1	30.2	46.1	79.2	106.7
WRSA305A	910.5	225.0	138.1	205.5	221.6	223.6	224.2
WRSA305B	908.5	407.9	324.6	406.3	406.9	407.5	407.8
WRSA305C	906.0	808.3	422.9	700.7	758.3	790.0	803.2
WRSA305D	913.0	431.6	378.1	430.0	431.1	431.3	431.5
WRSA306	910.0	619.4	76.0	190.1	262.2	361.1	569.0
WRSA307	910.0	254.1	0.0	70.7	147.5	207.9	252.9
WRSA309	914.0	635.5	4.2	43.7	156.8	294.3	405.3
- continued -							

Appendix Table C11. Continued							
	Approx.		Flood Event Size				
Storage Area	Field Elevation[a]	Size	10-yr	25-yr	50-yr	100-yr	500-yr
		---------------------------------- acres --------------------------------------					
WRSA311	907.0	305.2	155.9	284.4	294.9	301.0	304.7
WRSA312	905.0	631.3	194.5	587.6	624.1	629.6	631.2
DIVSA86	912.5	576.3	0.0	1.2	16.0	85.2	134.7
DIVSA87	910.5	520.0	0.1	5.6	458.1	519.8	519.9
DIVSA88	910.5	517.6	77.9	297.2	516.2	517.1	517.3
DIVSA89	908.0	298.2	142.0	291.1	296.7	297.6	298.1
DIVSA90	906.0	216.0	10.8	201.4	213.3	215.3	215.9
WRSA350	910.0	274.3	7.7	274.3	274.3	274.3	274.3
WRSA351	908.0	308.7	43.4	305.1	306.4	307.3	307.7
WRSA352	910.5	296.9	0.0	150.0	202.4	227.2	256.6
WRSA353	917.0	291.9	0.0	5.3	11.5	63.5	229.3
WRSA354	918.0	295.3	3.8	38.3	63.4	76.6	275.8
WRSA355	914.5	415.4	20.9	124.4	225.0	335.2	411.4
WRSA356	917.5	622.2	17.0	50.2	120.7	526.4	619.1
WRSA357	919.0	614.4	16.0	56.7	92.5	370.5	607.3
WRSA358	921.0	491.6	0.7	81.3	120.8	287.4	436.8
WRSA361	907.0	192.2	89.4	190.5	192.1	192.2	192.2
WRSA363	911.0	268.2	0.1	188.8	234.3	260.6	267.4
WRSA364	912.0	251.8	0.3	104.6	129.5	152.8	203.1
WRSA373	927.5	631.8	0.0	0.0	0.0	0.0	1.0
WRSA378	926.0	156.1	0.0	0.0	0.0	0.1	7.7
WRSA383	923.5	152.7	0.0	0.0	0.0	0.0	0.1
WRSA384	925.0	155.0	0.0	0.0	0.0	0.0	35.0
WRSA389	921.5	150.7	0.0	0.0	0.1	0.2	0.3
WRSA390	913.0	268.9	5.4	18.6	27.4	42.3	89.5
WRSA907	913.0	393.9	1.2	106.4	179.2	220.8	262.5
Totals		41,915.3	2,493.3	6,123.4	8,219.5	10,705.6	19,196.5

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C12. Designation of Storage Areas in Common Hydrology Groups, by Size of Flood Event, FM Diversion Staging Area					
Storage Area	Flood Event Size				
	10-yr	25-yr	50-yr	100-yr	500-yr
	---------------------------------- Group Number and Description of Common Hydrology ----------------------------------				
CHRSA01	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
CHRSA02	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
CHRSA03	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
CHRSA04	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
CHRSA05	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
CHRSA06	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
CHRSA07	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
CHRSA08	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
CHRSA09	1 No flooding	1 No flooding	1 No flooding	3 Floods, longer	3 Floods, longer
CHRSA10	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
CHRSA11	1 No flooding	1 No flooding	1 No flooding	1 No flooding	2 Floods, same
CHRSA12	1 No flooding	1 No flooding	1 No flooding	1 No flooding	3 Floods, longer
CHRSA13	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
CHRSA14	1 No flooding	1 No flooding	1 No flooding	1 No flooding	3 Floods, longer
CHRSA15	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
CHRSA16	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
CHRSA17	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA27	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA28	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA29	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA30	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA31	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA32	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA33	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WLVSA34	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA34a	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
- continued -					

Appendix Table C12. Continued					
Storage Area	Flood Event Size				
	10-yr	25-yr	50-yr	100-yr	500-yr
	---------------------------------- Group Number and Description of Common Hydrology ----------------------------------				
WLVSA35	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WLVSA36	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA37	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA38	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA39	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA40	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA41	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods
WLVSA42	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods
WLVSA42a	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods
WLVSA43	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods
WLVSA44	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods
WLVSA45	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA46	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA47	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA48	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WLVSA49	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WLVSA50	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer
WLVSA51	1 No flooding	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods
WLVSA51a	1 No flooding	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods
WLVSA53	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA54	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WLVSA55	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WLVSA56	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA57	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA58	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
- continued -					

Appendix Table C12. Continued					
Storage Area	Flood Event Size				
	10-yr	25-yr	50-yr	100-yr	500-yr
	---------------------------------- Group Number and Description of Common Hydrology ----------------------------------				
WLVSA59	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA63	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA64	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA65	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA66	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer
WLVSA67	2 Floods, same	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer
WLVSA72	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	3 Floods, longer
WRSA284	1 No flooding	1 No flooding	1 No flooding	1 No flooding	1 No flooding
WRSA289	1 No flooding	1 No flooding	1 No flooding	5 No flood, Now floods	5 No flood, Now floods
WRSA294	1 No flooding	5 No flood, Now floods	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer
WRSA299	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA300	4 Floods, shorter	3 Floods, longer	3 Floods, longer	2 Floods, same	4 Floods, shorter
WRSA302	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA304	4 Floods, shorter	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA305A	4 Floods, shorter	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA305B	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA305C	2 Floods, same	3 Floods, longer	2 Floods, same	4 Floods, shorter	4 Floods, shorter
WRSA305D	4 Floods, shorter	3 Floods, longer	3 Floods, longer	3 Floods, longer	2 Floods, same
WRSA306	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA307	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA309	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA311	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA312	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA314	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA315	5 No flood, Now floods	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA316	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA317A	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	2 Floods, same
WRSA317B	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA350	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA351	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA352	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
- continued -					

Appendix Table C12. Continued					
Storage Area	Flood Event Size				
	10-yr	25-yr	50-yr	100-yr	500-yr
	---------------------------------- Group Number and Description of Common Hydrology ----------------------------------				
WRSA353	1 No flooding	5 No flood, Now floods	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA354	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA355	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	2 Floods, same
WRSA356	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	2 Floods, same
WRSA357	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA358	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA361	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA363	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA364	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA373	1 No flooding	1 No flooding	1 No flooding	1 No flooding	1 No flooding
WRSA378	1 No flooding	1 No flooding	1 No flooding	1 No flooding	3 Floods, longer
WRSA383	1 No flooding	1 No flooding	1 No flooding	1 No flooding	1 No flooding
WRSA384	1 No flooding	1 No flooding	1 No flooding	1 No flooding	2 Floods, same
WRSA389	1 No flooding	1 No flooding	3 Floods, longer	3 Floods, longer	3 Floods, longer
WRSA390	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	4 Floods, shorter
WRSA907	2 Floods, same	3 Floods, longer	3 Floods, longer	3 Floods, longer	2 Floods, same

Appendix Table C13. Duration of Water Inundation, by Storage Area, 1997-Like Flood Event, With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area

		Days of Water above Storage Area Elevation	
		Existing Conditions	With Diversion Staging Area
Storage Area	Approx. Field Elevation[a]	1997-Like Event	1997-Like Event
CHRSA01	915.0	0	15.5
CHRSA02	914.5	0	16.5
CHRSA03	919.5	0	7.5
CHRSA04	918.0	0	12.5
CHRSA05	921.0	0	5.5
CHRSA06	921.5	0	4.5
CHRSA07	913.0	18	22
CHRSA08	918.5	0	13
CHRSA09	922.5	0	0
CHRSA10	920.5	0	8.5
CHRSA11	924.5	0	0
CHRSA12	924.5	0	0
CHRSA13	915.0	19	22
CHRSA14	924.0	0	0
CHRSA15	919.0	11	15.5
CHRSA16	917.0	15.5	19
CHRSA17	919.5	13.5	16.5
WLVSA27	911.0	11	21.5
WLVSA28	913.0	0	18.5
WLVSA29	913.0	0	18.5
WLVSA30	915.5	0	15
WLVSA31	919.0	0	8.5
WLVSA32	919.5	0	7
WLVSA33	915.0	0	15.5
WLVSA34	913.0	3.5	18.5
WLVSA34a	915.0	0	15.5
WLVSA35	905.0	23.5	25.5
WLVSA36	909.0	19	23.5
WLVSA37	910.0	16.5	22.5
WLVSA38	912.0	12.5	20.5
WLVSA39	918.5	0	10.5
WLVSA40	918.5	0	11
WLVSA41	921.0	0	0
WLVSA42	921.0	0	0
WLVSA42a	922.0	0	0

- continued -

Appendix Table C13. Continued			
		Days of Water above Storage Area Elevation	
		Existing Conditions	With Diversion Staging Area
Storage Area	Approx. Field Elevation[a]	1997-Like Event	1997-Like Event
WLVSA43	921.0	0	0
WLVSA44	922.0	0	0
WLVSA45	913.0	7	18.5
WLVSA46	913.0	10.5	19
WLVSA47	913.0	16	21
WLVSA48	920.0	0	6
WLVSA49	920.0	0	5
WLVSA50	922.0	0	0
WLVSA51	923.5	0	0
WLVSA51a	923.0	0	0
WLVSA53	922.0	0	0.5
WLVSA54	921.5	0	0
WLVSA55	921.0	0	4.5
WLVSA56	915.0	13	18.5
WLVSA57	921.0	0	7.5
WLVSA58	921.0	0	7.5
WLVSA59	922.0	0	6.5
WLVSA63	922.0	0	8
WLVSA64	922.0	0	8
WLVSA65	919.0	11	15
WLVSA66	923.5	0	6
WLVSA67	921.5	3	10.5
WLVSA72	924.5	0	0
WRSA284	923.0	0	0
WRSA289	922.0	0	0
WRSA294	919.5	0	6.5
WRSA299	911.0	23.5	23.5
WRSA300	908.0	32	30.5
WRSA302	912.0	12.5	20
WRSA304	911.5	22.5	22
WRSA305A	910.5	24.5	24
WRSA305B	908.5	30.5	28.5
WRSA305C	906.0	36	36
WRSA305D	913.0	19	20
WRSA306	910.0	20	23.5
WRSA307	910.0	18	23

- continued -

Appendix Table C13. Continued												
		Days of Water above Storage Area Elevation										
		Existing Conditions						With Diversion Staging Area				
Storage Area	Approx. Field Elevation[a]				1997-Like Event						1997-Like Event	
WRSA309	914.0				16.5						18.5	
WRSA311	907.0				27						26	
WRSA312	905.0				32.5						30	
WRSA314	912.5				8						19	
WRSA315	910.5				1.5						21	
WRSA316	910.5				20.5						21	
WRSA317A	908.0				24						25.5	
WRSA317B	906.0				22						24.5	
WRSA350	910.0				20						23.5	
WRSA351	908.0				24						25	
WRSA352	910.5				18.5						22.5	
WRSA353	917.0				0						12.5	
WRSA354	918.0				14.5						16	
WRSA355	914.5				24.5						24.5	
WRSA356	917.5				21.5						22	
WRSA357	919.0				19						19.5	
WRSA358	921.0				13						14.5	
WRSA361	907.0				27						26	
WRSA363	911.0				18						22.5	
WRSA364	912.0				18.5						21	
WRSA373	927.5				0						0	
WRSA378	926.0				0						0	
WRSA383	923.5				0						0	
WRSA384	925.0				0						0	
WRSA389	921.5				0						7	
WRSA390	913.0				25.5						25	
WRSA907	913.0				19.5						20	

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C14. Time from Activation of Staging Area to Inundation, by Storage Area, 1997-like Flood Event, With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
CHRSA01	915.0			0						3.5		
CHRSA02	914.5			0						3.5		
CHRSA03	919.5			0						6.5		
CHRSA04	918.0			0						5.5		
CHRSA05	921.0			0						7		
CHRSA06	921.5			0						6.5		
CHRSA07	913.0			2.5						1.5		
CHRSA08	918.5			0						4		
CHRSA09	922.5			0						0		
CHRSA10	920.5			0						5.5		
CHRSA11	924.5			0						0		
CHRSA12	924.5			0						0		
CHRSA13	915.0			2						1.5		
CHRSA14	924.0			0						0		
CHRSA15	919.0			4.5						3		
CHRSA16	917.0			3						2		
CHRSA17	919.5			3.5						3		
WLVSA27s	911.0			5						2		
WLVSA28s	913.0			0						2.5		
WLVSA29s	913.0			0						2.5		
WLVSA30s	915.5			0						3.5		
WLVSA31s	919.0			0						6.5		
WLVSA32	919.5			0						6.5		
WLVSA33	915.0			0						3.5		
WLVSA34	913.0			6.5						2.5		
WLVSA34a	915.0			0						3.5		
WLVSA35	905.0			1.5						0.5		
WLVSA36	909.0			3						1.5		
WLVSA37	910.0			3						1.5		
WLVSA38	912.0			3						2		
WLVSA39	918.5			0						5		
WLVSA40	918.5			0						5		
WLVSA41	921.0			0						0		
WLVSA42	921.0			0						0		
WLVSA42a	922.0			0						0		
WLVSA43	921.0			0						0		

- continued -

Appendix Table C14. Continued												
Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
WLVSA44	922.0			0						0		
WLVSA45	913.0			3						2.5		
WLVSA46	913.0			5.5						3		
WLVSA47	913.0			3.5						2		
WLVSA48	920.0			0						6.5		
WLVSA49	920.0			0						7		
WLVSA50	922.0			0						0		
WLVSA51	923.5			0						0		
WLVSA51a	923.0			0						0		
WLVSA53	922.0			0						4.5		
WLVSA54	921.5			0						0		
WLVSA55	921.0			0						6.5		
WLVSA56	915.0			4						2.5		
WLVSA57	921.0			0						6		
WLVSA58	921.0			0						6		
WLVSA59	922.0			0						6		
WLVSA63	922.0			0						5.5		
WLVSA64	922.0			0						5.5		
WLVSA65	919.0			4.5						3.5		
WLVSA66	923.5			0						6		
WLVSA67	921.5			3						2.5		
WLVSA72	924.5			0						0		
WRSA284	923.0			0						0		
WRSA289	922.0			0						0		
WRSA294	919.5			0						5.5		
WRSA299	911.0			1						0.5		
WRSA300	908.0			0						0		
WRSA302	912.0			5						2.5		
WRSA304	911.5			1.5						1		
WRSA305A	910.5			0.5						0.5		
WRSA305B	908.5			0						0		
WRSA305C	906.0			0						0		
WRSA305D	913.0			2.5						1.5		
WRSA306	910.0			3						1.5		
WRSA307	910.0			3.5						1.5		
WRSA309	914.0			3						2.5		
WRSA311	907.0			0						0		
- continued -												

Appendix Table C14. Continued

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area for Field to be Inundated										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
WRSA312	905.0			0						0		
WRSA314	912.5			4.5						2		
WRSA315	910.5			8.5						0.5		
WRSA316	910.5			2.5						0.5		
WRSA317A	908.0			1						0.5		
WRSA317B	906.0			2						1		
WRSA350	910.0			3						1.5		
WRSA351	908.0			1						0.5		
WRSA352	910.5			3.5						2.5		
WRSA353	917.0			0						4		
WRSA354	918.0			3						3		
WRSA355	914.5			0						0		
WRSA356	917.5			1						0.5		
WRSA357	919.0			1.5						1.5		
WRSA358	921.0			3						3		
WRSA361	907.0			0						0		
WRSA363	911.0			3.5						2		
WRSA364	912.0			3						3		
WRSA373	927.5			0						0		
WRSA378	926.0			0						0		
WRSA383	923.5			0						0		
WRSA384	925.0			0						0		
WRSA389	921.5			0						6		
WRSA390	913.0			0						0		
WRSA907	913.0			2						2		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C15. Time from Activation of Staging Area to When Flood Water Leaves, by Storage Area, 1997-Like Flood Event, With and Without Diversion Conditions, FM Diversion Staging Area, Phase 7.2 HEC-RAS Modeling With Inclusion of Surveyed Culverts in Staging Area												
Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
CHRSA01	915.0			0						19		
CHRSA02	914.5			0						20		
CHRSA03	919.5			0						14		
CHRSA04	918.0			0						18		
CHRSA05	921.0			0						12.5		
CHRSA06	921.5			0						11		
CHRSA07	913.0			20.5						23.5		
CHRSA08	918.5			0						17		
CHRSA09	922.5			0						0		
CHRSA10	920.5			0						14		
CHRSA11	924.5			0						0		
CHRSA12	924.5			0						0		
CHRSA13	915.0			21						23.5		
CHRSA14	924.0			0						0		
CHRSA15	919.0			15.5						18.5		
CHRSA16	917.0			18.5						21		
CHRSA17	919.5			17						19.5		
WLVSA27	911.0			16						23.5		
WLVSA28	913.0			0						21		
WLVSA29	913.0			0						21		
WLVSA30	915.5			0						18.5		
WLVSA31	919.0			0						15		
WLVSA32	919.5			0						13.5		
WLVSA33	915.0			0						19		
WLVSA34	913.0			10						21		
WLVSA34a	915.0			0						19		
WLVSA35	905.0			25						26		
WLVSA36	909.0			22						25		
WLVSA37	910.0			19.5						24		
WLVSA38	912.0			15.5						22.5		
WLVSA39	918.5			0						15.5		
WLVSA40	918.5			0						16		
WLVSA41	921.0			0						0		
WLVSA42	921.0			0						0		
WLVSA42a	922.0			0						0		
- continued -												

Appendix Table C15. Continued

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
WLVSA43	921.0			0						0		
WLVSA44	922.0			0						0		
WLVSA45	913.0			10						21		
WLVSA46	913.0			16						22		
WLVSA47	913.0			19.5						23		
WLVSA48	920.0			0						12.5		
WLVSA49	920.0			0						12		
WLVSA50	922.0			0						0		
WLVSA51	923.5			0						0		
WLVSA51a	923.0			0						0		
WLVSA53	922.0			0						5		
WLVSA54	921.5			0						0		
WLVSA55	921.0			0						11		
WLVSA56	915.0			17						21		
WLVSA57	921.0			0						13.5		
WLVSA58	921.0			0						13.5		
WLVSA59	922.0			0						12.5		
WLVSA63	922.0			0						13.5		
WLVSA64	922.0			0						13.5		
WLVSA65	919.0			15.5						18.5		
WLVSA66	923.5			0						12		
WLVSA67	921.5			6						13		
WLVSA72	924.5			0						0		
WRSA284	923.0			0						0		
WRSA289	922.0			0						0		
WRSA294	919.5			0						12		
WRSA299	911.0			24.5						24		
WRSA300	908.0			32						30.5		
WRSA302	912.0			17.5						22.5		
WRSA304	911.5			24						23		
WRSA305A	910.5			25						24.5		
WRSA305B	908.5			30.5						28.5		
WRSA305C	906.0			36						36		
WRSA305D	913.0			21.5						21.5		
WRSA306	910.0			23						25		
WRSA307	910.0			21.5						24.5		

- continued -

Appendix Table C15. Continued

Storage Area	Approx. Field Elevation[a]	Days from Activation of Staging Area Until Flood Water Leaves the Storage Area										
		Existing Conditions						With Diversion Staging Area				
				1997						1997		
WRSA309	914.0			19.5						21		
WRSA311	907.0			27						26		
WRSA312	905.0			32.5						30		
WRSA314	912.5			12.5						21		
WRSA315	910.5			10						21.5		
WRSA316	910.5			23						21.5		
WRSA317A	908.0			25						26		
WRSA317B	906.0			24						25.5		
WRSA350	910.0			23						25		
WRSA351	908.0			25						25.5		
WRSA352	910.5			22						25		
WRSA353	917.0			0						16.5		
WRSA354	918.0			17.5						19		
WRSA355	914.5			24.5						24.5		
WRSA356	917.5			22.5						22.5		
WRSA357	919.0			20.5						21		
WRSA358	921.0			16						17.5		
WRSA361	907.0			27						26		
WRSA363	911.0			21.5						24.5		
WRSA364	912.0			21.5						24		
WRSA373	927.5			0						0		
WRSA378	926.0			0						0		
WRSA383	923.5			0						0		
WRSA384	925.0			0						0		
WRSA389	921.5			0						13		
WRSA390	913.0			25.5						25		
WRSA907	913.0			21.5						22		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C16. Acreage of Storage Areas That Do Not Flood in Either the With or Without Diversion Conditions, by Storage Area, 1997-Like Flood Event (Hydrology Group One)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0					
CHRSA08	918.5					
CHRSA09	922.5			301		
CHRSA10	920.5					
CHRSA11	924.5			305		
CHRSA12	924.5			327		
CHRSA13	915.0					
CHRSA14	924.0			317		
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0					
WLVSA34a	915.0					
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0			1,466		
WLVSA42	921.0			631		
WLVSA42a	922.0			644		
WLVSA43	921.0			635		
- continued -						

Appendix Table C16. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WLVSA44	922.0			179		
WLVSA45	913.0					
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0			630		
WLVSA51	923.5			634		
WLVSA51a	923.0			642		
WLVSA53	922.0					
WLVSA54	921.5			334		
WLVSA55	921.0					
WLVSA56	915.0					
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0					
WLVSA66	923.5					
WLVSA67	921.5					
WLVSA72	924.5			593		
WRSA284	923.0			597		
WRSA289	922.0			629		
WRSA294	919.5					
WRSA299	911.0					
WRSA300	908.0					
WRSA302	912.0					
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0					
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0					
- continued -						

Appendix Table C16. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WRSA312	905.0					
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5					
WRSA353	917.0					
WRSA354	918.0					
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0					
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5			632		
WRSA378	926.0			156		
WRSA383	923.5			153		
WRSA384	925.0			155		
WRSA389	921.5					
WRSA390	913.0					
WRSA907	913.0					
Total				9,960		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C17. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is the Same Duration With and Without Diversion Conditions, by Storage Area, 1997-Like Flood Event (Hydrology Group Two)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres ------------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0					
CHRSA08	918.5					
CHRSA09	922.5					
CHRSA10	920.5					
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0					
WLVSA34a	915.0					
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
- continued -						

Appendix Table C17. Continued

Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres ------------------------------				
WLVSA43	921.0					
WLVSA44	922.0					
WLVSA45	913.0					
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0					
WLVSA54	921.5					
WLVSA55	921.0					
WLVSA56	915.0					
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0					
WLVSA66	923.5					
WLVSA67	921.5					
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					
WRSA299	911.0			627		
WRSA300	908.0					
WRSA302	912.0					
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0			808		
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					

- continued -

Appendix Table C17. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres ------------------------------				
WRSA311	907.0					
WRSA312	905.0					
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5					
WRSA353	917.0					
WRSA354	918.0					
WRSA355	914.5			415		
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0					
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5					
WRSA390	913.0					
WRSA907	913.0					
Total				1,850		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C18. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is Longer With the Diversion, by Storage Area, 1997-Like Flood Event (Hydrology Group Three)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0			151		
CHRSA08	918.5					
CHRSA09	922.5					
CHRSA10	920.5					
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0			629		
CHRSA14	924.0					
CHRSA15	919.0			324		
CHRSA16	917.0			629		
CHRSA17	919.5			839		
WLVSA27	911.0			430		
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0			326		
WLVSA34a	915.0					
WLVSA35	905.0			409		
WLVSA36	909.0			374		
WLVSA37	910.0			249		
WLVSA38	912.0			222		
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C18. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WLVSA44	922.0					
WLVSA45	913.0			309		
WLVSA46	913.0			630		
WLVSA47	913.0			625		
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0					
WLVSA54	921.5					
WLVSA55	921.0					
WLVSA56	915.0			629		
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0			127		
WLVSA66	923.5					
WLVSA67	921.5			726		
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					
WRSA299	911.0					
WRSA300	908.0					
WRSA302	912.0			404		
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0					
WRSA305D	913.0			432		
WRSA306	910.0			619		
WRSA307	910.0			254		
WRSA309	914.0			636		
WRSA311	907.0					
- continued -						

Appendix Table C18. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
WRSA312	905.0					
WRSA314	912.5			619		
WRSA315	910.5			613		
WRSA316	910.5			611		
WRSA317A	908.0			353		
WRSA317B	906.0			230		
WRSA350	910.0			274		
WRSA351	908.0			309		
WRSA352	910.5			297		
WRSA353	917.0					
WRSA354	918.0			295		
WRSA355	914.5					
WRSA356	917.5			622		
WRSA357	919.0			614		
WRSA358	921.0			492		
WRSA361	907.0					
WRSA363	911.0			268		
WRSA364	912.0			252		
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5					
WRSA390	913.0					
WRSA907	913.0			394		
Total				15,822		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C19. Acreage of Storage Areas That Flood With and Without Diversion, but Inundation is Shorter With the Diversion, by Storage Area, 1997-Like Flood Event (Hydrology Group Four)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
CHRSA01	915.0					
CHRSA02	914.5					
CHRSA03	919.5					
CHRSA04	918.0					
CHRSA05	921.0					
CHRSA06	921.5					
CHRSA07	913.0					
CHRSA08	918.5					
CHRSA09	922.5					
CHRSA10	920.5					
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0					
WLVSA29	913.0					
WLVSA30	915.5					
WLVSA31	919.0					
WLVSA32	919.5					
WLVSA33	915.0					
WLVSA34	913.0					
WLVSA34a	915.0					
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5					
WLVSA40	918.5					
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C19. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WLVSA44	922.0					
WLVSA45	913.0					
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0					
WLVSA49	920.0					
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0					
WLVSA54	921.5					
WLVSA55	921.0					
WLVSA56	915.0					
WLVSA57	921.0					
WLVSA58	921.0					
WLVSA59	922.0					
WLVSA63	922.0					
WLVSA64	922.0					
WLVSA65	919.0					
WLVSA66	923.5					
WLVSA67	921.5					
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5					
WRSA299	911.0					
WRSA300	908.0			626		
WRSA302	912.0					
WRSA304	911.5			635		
WRSA305A	910.5			225		
WRSA305B	908.5			408		
WRSA305C	906.0					
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0			305		
- continued -						

Appendix Table C19. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WRSA312	905.0			631		
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5					
WRSA353	917.0					
WRSA354	918.0					
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0			192		
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5					
WRSA390	913.0			269		
WRSA907	913.0					
Total				3,291		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C20. Acreage of Storage Areas That Flood With the Diversion but Would Not Flood With Existing Conditions, by Storage Area, 1997-Like Flood Event (Hydrology Group Five)						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
CHRSA01	915.0			307		
CHRSA02	914.5			305		
CHRSA03	919.5			304		
CHRSA04	918.0			284		
CHRSA05	921.0			320		
CHRSA06	921.5			117		
CHRSA07	913.0					
CHRSA08	918.5			161		
CHRSA09	922.5					
CHRSA10	920.5			326		
CHRSA11	924.5					
CHRSA12	924.5					
CHRSA13	915.0					
CHRSA14	924.0					
CHRSA15	919.0					
CHRSA16	917.0					
CHRSA17	919.5					
WLVSA27	911.0					
WLVSA28	913.0			290		
WLVSA29	913.0			935		
WLVSA30	915.5			629		
WLVSA31	919.0			1,266		
WLVSA32	919.5			1,270		
WLVSA33	915.0			631		
WLVSA34	913.0					
WLVSA34a	915.0			627		
WLVSA35	905.0					
WLVSA36	909.0					
WLVSA37	910.0					
WLVSA38	912.0					
WLVSA39	918.5			469		
WLVSA40	918.5			633		
WLVSA41	921.0					
WLVSA42	921.0					
WLVSA42a	922.0					
WLVSA43	921.0					
- continued -						

Appendix Table C20. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WLVSA44	922.0					
WLVSA45	913.0					
WLVSA46	913.0					
WLVSA47	913.0					
WLVSA48	920.0			308		
WLVSA49	920.0			328		
WLVSA50	922.0					
WLVSA51	923.5					
WLVSA51a	923.0					
WLVSA53	922.0			638		
WLVSA54	921.5					
WLVSA55	921.0			302		
WLVSA56	915.0					
WLVSA57	921.0			210		
WLVSA58	921.0			173		
WLVSA59	922.0			227		
WLVSA63	922.0			228		
WLVSA64	922.0			400		
WLVSA65	919.0					
WLVSA66	923.5			212		
WLVSA67	921.5					
WLVSA72	924.5					
WRSA284	923.0					
WRSA289	922.0					
WRSA294	919.5			625		
WRSA299	911.0					
WRSA300	908.0					
WRSA302	912.0					
WRSA304	911.5					
WRSA305A	910.5					
WRSA305B	908.5					
WRSA305C	906.0					
WRSA305D	913.0					
WRSA306	910.0					
WRSA307	910.0					
WRSA309	914.0					
WRSA311	907.0					
- continued -						

Appendix Table C20. Continued						
Storage Area	Approx. Field Elevation[a]	Flood Event Size				
				1997		
		------------------------- acres -----------------------------				
WRSA312	905.0					
WRSA314	912.5					
WRSA315	910.5					
WRSA316	910.5					
WRSA317A	908.0					
WRSA317B	906.0					
WRSA350	910.0					
WRSA351	908.0					
WRSA352	910.5					
WRSA353	917.0			292		
WRSA354	918.0					
WRSA355	914.5					
WRSA356	917.5					
WRSA357	919.0					
WRSA358	921.0					
WRSA361	907.0					
WRSA363	911.0					
WRSA364	912.0					
WRSA373	927.5					
WRSA378	926.0					
WRSA383	923.5					
WRSA384	925.0					
WRSA389	921.5			151		
WRSA390	913.0					
WRSA907	913.0					
Total				12,968		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C21. Inundated Acres, With FM Diversion Staging Area, 1997-Like Flood Event							
	Approx.		Flood Event Size				
	Field	Size			1997		
Storage Area	Elevation[a]	---------------------------------- acres --------------------------------------					
CHRSA01	915.0	306.7			307		
CHRSA02	914.5	305.0			305		
CHRSA03	919.5	304.2			304		
CHRSA04	918.0	283.6			284		
CHRSA05	921.0	320.4			320		
CHRSA06	921.5	116.6			117		
CHRSA07	913.0	150.5			151		
CHRSA08	918.5	160.5			161		
CHRSA09	922.5	301.1			0		
CHRSA10	920.5	326.5			326		
CHRSA11	924.5	304.7			0		
CHRSA12	924.5	326.9			0		
CHRSA13	915.0	628.8			629		
CHRSA14	924.0	310.3			0		
CHRSA15	919.0	323.7			324		
CHRSA16	917.0	629.0			629		
CHRSA17	919.5	838.7			839		
WLVSA27S	911.0	201.2			430		
WLVSA28S	913.0	124.5			290		
WLVSA29S	913.0	389.5			935		
WLVSA30S	915.5	258.8			629		
WLVSA31S	919.0	510.2			1,266		
WLVSA32	919.5	1,269.8			1,270		
WLVSA33	915.0	631.1			631		
WLVSA34	913.0	325.5			326		
WLVSA34a	915.0	627.1			627		
WLVSA35	905.0	409.2			409		
WLVSA36	909.0	373.8			374		
WLVSA37	910.0	249.4			249		
WLVSA38	912.0	221.6			222		
WLVSA39	918.5	469.3			469		
WLVSA40	918.5	633.0			633		
WLVSA41	921.0	1,466.5			0		
WLVSA42	921.0	630.6			0		
WLVSA42a	922.0	644.3			0		
WLVSA43	921.0	635.1			0		
- continued-							

Appendix Table C21. Continued							
Storage Area	Approx. Field Elevation[a]	Size	Flood Event Size				
					1997		
		---------------------------------- acres --------------------------------------					
WLVSA44	922.0	178.8			0		
WLVSA45	913.0	309.2			309		
WLVSA46	913.0	629.4			630		
WLVSA47	913.0	625.5			625		
WLVSA48	920.0	308.4			308		
WLVSA49	920.0	327.9			328		
WLVSA50	922.0	630.2			0		
WLVSA51	923.5	634.2			0		
WLVSA51a	923.0	641.6			0		
WLVSA53	922.0	637.7			638		
WLVSA54	921.5	334.0			0		
WLVSA55	921.0	301.7			302		
WLVSA56	915.0	629.0			629		
WLVSA57	921.0	210.4			210		
WLVSA58	921.0	173.3			173		
WLVSA59	922.0	227.3			227		
WLVSA63	922.0	228.0			228		
WLVSA64	922.0	400.2			400		
WLVSA65	919.0	127.0			127		
WLVSA66	923.5	212.3			212		
WLVSA67	921.5	726.1			726		
WLVSA72	924.5	593.2			0		
WRSA284	923.0	597.4			0		
WRSA289	922.0	629.3			0		
WRSA294	919.5	625.3			625		
WRSA299	911.0	626.9			627		
WRSA300	908.0	626.3			626		
WRSA302	912.0	241.4			404		
WRSA304	911.5	634.8			635		
WRSA305A	910.5	225.0			225		
WRSA305B	908.5	407.9			408		
WRSA305C	906.0	808.3			808		
WRSA305D	913.0	431.6			432		
WRSA306	910.0	502.4			619		
WRSA307	910.0	213.8			254		
WRSA309	914.0	635.5			636		
WRSA311	907.0	305.2			305		
- continued -							

Appendix Table C21. Continued							
	Approx. Field		Flood Event Size				
Storage Area	Elevation[a]	Size			1997		
		---------------------------------- acres --------------------------------------					
WRSA312	905.0	631.3			631		
DIVSA86	912.5	575.9			619		
DIVSA87	910.5	520.1			613		
DIVSA88	910.5	517.6			611		
DIVSA89	908.0	298.2			353		
DIVSA90	906.0	216.0			230		
WRSA350	910.0	274.3			274		
WRSA351	908.0	308.7			309		
WRSA352	910.5	296.9			297		
WRSA353	917.0	291.9			292		
WRSA354	918.0	295.3			295		
WRSA355	914.5	415.4			415		
WRSA356	917.5	622.2			622		
WRSA357	919.0	614.4			614		
WRSA358	921.0	491.6			492		
WRSA361	907.0	192.2			192		
WRSA363	911.0	268.2			268		
WRSA364	912.0	251.8			252		
WRSA373	927.5	631.8			0		
WRSA378	926.0	156.1			0		
WRSA383	923.5	152.7			0		
WRSA384	925.0	155.0			0		
WRSA389	921.5	150.7			151		
WRSA390	913.0	268.9			269		
WRSA907	913.0	393.9			394		
Totals		44,285			33,931		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C22. Inundated Acres, With Current Conditions, 1997-Like Flood Event							
Storage Area	Approx. Field Elevation[a]	Size	Flood Event Size				
					1997		
		---------------------------------- acres --------------------------------------					
CHRSA01	915.0	306.7			0		
CHRSA02	914.5	305.0			0		
CHRSA03	919.5	304.2			0		
CHRSA04	918.0	283.6			0		
CHRSA05	921.0	320.4			0		
CHRSA06	921.5	116.6			0		
CHRSA07	913.0	150.5			151		
CHRSA08	918.5	160.5			0		
CHRSA09	922.5	301.1			0		
CHRSA10	920.5	326.5			0		
CHRSA11	924.5	304.7			0		
CHRSA12	924.5	326.9			0		
CHRSA13	915.0	628.8			629		
CHRSA14	924.0	310.3			0		
CHRSA15	919.0	323.7			324		
CHRSA16	917.0	629.0			629		
CHRSA17	919.5	838.7			839		
WLVSA27S	911.0	201.2			430		
WLVSA28S	913.0	124.5			0		
WLVSA29S	913.0	389.5			0		
WLVSA30S	915.5	258.8			0		
WLVSA31S	919.0	510.2			0		
WLVSA32	919.5	1,269.8			0		
WLVSA33	915.0	631.1			0		
WLVSA34	913.0	325.5			326		
WLVSA34a	915.0	627.1			0		
WLVSA35	905.0	409.2			409		
WLVSA36	909.0	373.8			374		
WLVSA37	910.0	249.4			249		
WLVSA38	912.0	221.6			222		
WLVSA39	918.5	469.3			0		
WLVSA40	918.5	633.0			0		
WLVSA41	921.0	1,466.5			0		
WLVSA42	921.0	630.6			0		
WLVSA42a	922.0	644.3			0		
WLVSA43	921.0	635.1			0		
WLVSA44	922.0	178.8			0		
- continued -							

Appendix Table C22. Continued							
Storage Area	Approx. Field Elevation[a]	Size	Flood Event Size				
					1997		
		---------------------------------- acres --------------------------------------					
WLVSA45	913.0	309.2			309		
WLVSA46	913.0	629.4			630		
WLVSA47	913.0	625.5			625		
WLVSA48	920.0	308.4			0		
WLVSA49	920.0	327.9			0		
WLVSA50	922.0	630.2			0		
WLVSA51	923.5	634.2			0		
WLVSA51a	923.0	641.6			0		
WLVSA53	922.0	637.7			0		
WLVSA54	921.5	334.0			0		
WLVSA55	921.0	301.7			0		
WLVSA56	915.0	629.0			629		
WLVSA57	921.0	210.4			0		
WLVSA58	921.0	173.3			0		
WLVSA59	922.0	227.3			0		
WLVSA63	922.0	228.0			0		
WLVSA64	922.0	400.2			0		
WLVSA65	919.0	127.0			127		
WLVSA66	923.5	212.3			0		
WLVSA67	921.5	726.1			726		
WLVSA72	924.5	593.2			0		
WRSA284	923.0	597.4			0		
WRSA289	922.0	629.3			0		
WRSA294	919.5	625.3			0		
WRSA299	911.0	626.9			627		
WRSA300	908.0	626.3			626		
WRSA302	912.0	404.0			404		
WRSA304	911.5	634.8			635		
WRSA305A	910.5	225.0			225		
WRSA305B	908.5	407.9			408		
WRSA305C	906.0	808.3			808		
WRSA305D	913.0	431.6			432		
WRSA306	910.0	619.4			619		
WRSA307	910.0	254.1			254		
WRSA309	914.0	635.5			636		
WRSA311	907.0	305.2			305		
WRSA312	905.0	631.3			631		
- continued -							

Appendix Table C22. Continued							
Storage Area	Approx. Field Elevation[a]	Size	Flood Event Size				
					1997		
		---------------------------------- acres --------------------------------------					
DIVSA86	912.5	576.3			619		
DIVSA87	910.5	520.0			613		
DIVSA88	910.5	517.6			611		
DIVSA89	908.0	298.2			353		
DIVSA90	906.0	216.0			230		
WRSA350	910.0	274.3			274		
WRSA351	908.0	308.7			309		
WRSA352	910.5	296.9			297		
WRSA353	917.0	291.9			0		
WRSA354	918.0	295.3			295		
WRSA355	914.5	415.4			415		
WRSA356	917.5	622.2			622		
WRSA357	919.0	614.4			614		
WRSA358	921.0	491.6			492		
WRSA361	907.0	192.2			192		
WRSA363	911.0	268.2			268		
WRSA364	912.0	251.8			252		
WRSA373	927.5	631.8			0		
WRSA378	926.0	156.1			0		
WRSA383	923.5	152.7			0		
WRSA384	925.0	155.0			0		
WRSA389	921.5	150.7			0		
WRSA390	913.0	268.9			269		
WRSA907	913.0	393.9			394		
Totals		44,285			20,963		

[a]Feet above mean seal level. Lowest estimated elevation for storage area.
Source: FM Diversion Authority (2015).

Appendix Table C23. Designation of Storage Areas in Common Hydrology Groups, 1997-Like Flood Event, FM Diversion Staging Area					
Storage Area	Flood Event				
			1997		
	---------------------------------- Group Number and Description of Common Hydrology -----------------------------------				
CHRSA01			5 Now Floods		
CHRSA02			5 Now Floods		
CHRSA03			5 Now Floods		
CHRSA04			5 Now Floods		
CHRSA05			5 Now Floods		
CHRSA06			5 Now Floods		
CHRSA07			3 Floods Longer		
CHRSA08			5 Now Floods		
CHRSA09			1 No Flooding		
CHRSA10			5 Now Floods		
CHRSA11			1 No Flooding		
CHRSA12			1 No Flooding		
CHRSA13			3 Floods Longer		
CHRSA14			1 No Flooding		
CHRSA15			3 Floods Longer		
CHRSA16			3 Floods Longer		
CHRSA17			3 Floods Longer		
WLVSA27			3 Floods Longer		
WLVSA28			5 Now Floods		
WLVSA29			5 Now Floods		
WLVSA30			5 Now Floods		
WLVSA31			5 Now Floods		
WLVSA32			5 Now Floods		
WLVSA33			5 Now Floods		
WLVSA34			3 Floods Longer		
WLVSA34a			5 Now Floods		
WLVSA35			3 Floods Longer		
WLVSA36			3 Floods Longer		
WLVSA37			3 Floods Longer		
WLVSA38			3 Floods Longer		
WLVSA39			5 Now Floods		
WLVSA40			5 Now Floods		
WLVSA41			1 No Flooding		
WLVSA42			1 No Flooding		
WLVSA42a			1 No Flooding		
WLVSA43			1 No Flooding		
- continued -					

Appendix Table C23. Continued					
Storage Area	Flood Event				
			1997		
	--------------------------------- Group Number and Description of Common Hydrology ---------------------------------				
WLVSA44			1 No Flooding		
WLVSA45			3 Floods Longer		
WLVSA46			3 Floods Longer		
WLVSA47			3 Floods Longer		
WLVSA48			5 Now Floods		
WLVSA49			5 Now Floods		
WLVSA50			1 No Flooding		
WLVSA51			1 No Flooding		
WLVSA51a			1 No Flooding		
WLVSA53			5 Now Floods		
WLVSA54			1 No Flooding		
WLVSA55			5 Now Floods		
WLVSA56			3 Floods Longer		
WLVSA57			5 Now Floods		
WLVSA58			5 Now Floods		
WLVSA59			5 Now Floods		
WLVSA63			5 Now Floods		
WLVSA64			5 Now Floods		
WLVSA65			3 Floods Longer		
WLVSA66			5 Now Floods		
WLVSA67			3 Floods Longer		
WLVSA72			1 No Flooding		
WRSA284			1 No Flooding		
WRSA289			1 No Flooding		
WRSA294			5 Now Floods		
WRSA299			4 Floods Shorter		
WRSA300			4 Floods Shorter		
WRSA302			3 Floods Longer		
WRSA304			4 Floods Shorter		
WRSA305A			4 Floods Shorter		
WRSA305B			4 Floods Shorter		
WRSA305C			2 Floods Same		
WRSA305D			2 Floods Same		
WRSA306			3 Floods Longer		
WRSA307			3 Floods Longer		
WRSA309			3 Floods Longer		
WRSA311			4 Floods Shorter		
- continued -					

Appendix Table C23. Continued					
Storage Area	Flood Event				
			1997		
	---------------------------------- Group Number and Description of Common Hydrology ----------------------------------				
WRSA312			4 Floods Shorter		
WRSA314			3 Floods Longer		
WRSA315			3 Floods Longer		
WRSA316			4 Floods Shorter		
WRSA317A			3 Floods Longer		
WRSA317B			3 Floods Longer		
WRSA350			3 Floods Longer		
WRSA351			3 Floods Longer		
WRSA352			3 Floods Longer		
WRSA353			5 Now Floods		
WRSA354			3 Floods Longer		
WRSA355			2 Floods Same		
WRSA356			2 Floods Same		
WRSA357			3 Floods Longer		
WRSA358			3 Floods Longer		
WRSA361			4 Floods Shorter		
WRSA363			3 Floods Longer		
WRSA364			3 Floods Longer		
WRSA373			1 No Flooding		
WRSA378			1 No Flooding		
WRSA383			1 No Flooding		
WRSA384			1 No Flooding		
WRSA389			5 Now Floods		
WRSA390			4 Floods Shorter		
WRSA907			3 Floods Longer		

Appendix Table C24. Acreage of Storage Areas based on the Difference between With Diversion and Without Diversion scenarios, 10-year Flood Event, Measuring Days from Activation of Staging Area until the Effects of Flooding are over (Inundation plus Dry-down)					
Difference between With Diversion and Without Diversion, Inundation plus Dry-down	10-year Flood Event				
	Cass County	Clay County	Richland County	Wilkin County	Total
--- days ---	-- acres --				
-0.5 days	1,918				1,918
0 days	10,952	18,324	8,733	2,896	40,905
0.5 days	849				849
16.5 days	613				613
Source: FM Diversion Authority (2015).					

Appendix Table C25. Acreage of Storage Areas based on the Difference between With Diversion and Without Diversion scenarios, 25-year Flood Event, Measuring Days from Activation of Staging Area until the Effects of Flooding are over (Inundation plus Dry-down)					
Difference between With Diversion and Without Diversion, Inundation plus Dry-down	25-year Flood Event				
	Cass County	Clay County	Richland County	Wilkin County	Total
--- days ---	---------- acres ----------				
0	629	7,371	3,857	2,769	14,626
1	1,842		1,728		3,570
1.5	880				880
2	1,147		415		1,562
2.5	1,266				1,266
3	826				826
3.5	1,137		839		1,976
4	2,368		1,258		3,626
4.5		409			409
5	484		151		635
5.5	404	1,628			2,032
6	619	249			868
6.5		309			309
7.5		222			222
16	625				625
17	304	1,270			1,574
17.5		1,266			1,266
18.5		469	485	127	1,081
19	292	633			925
20.5	591	1,256			1,847
21		631			631
21.5		1,551			1,551
22	918	630			1,548
23		430			430

Source: FM Diversion Authority (2015).

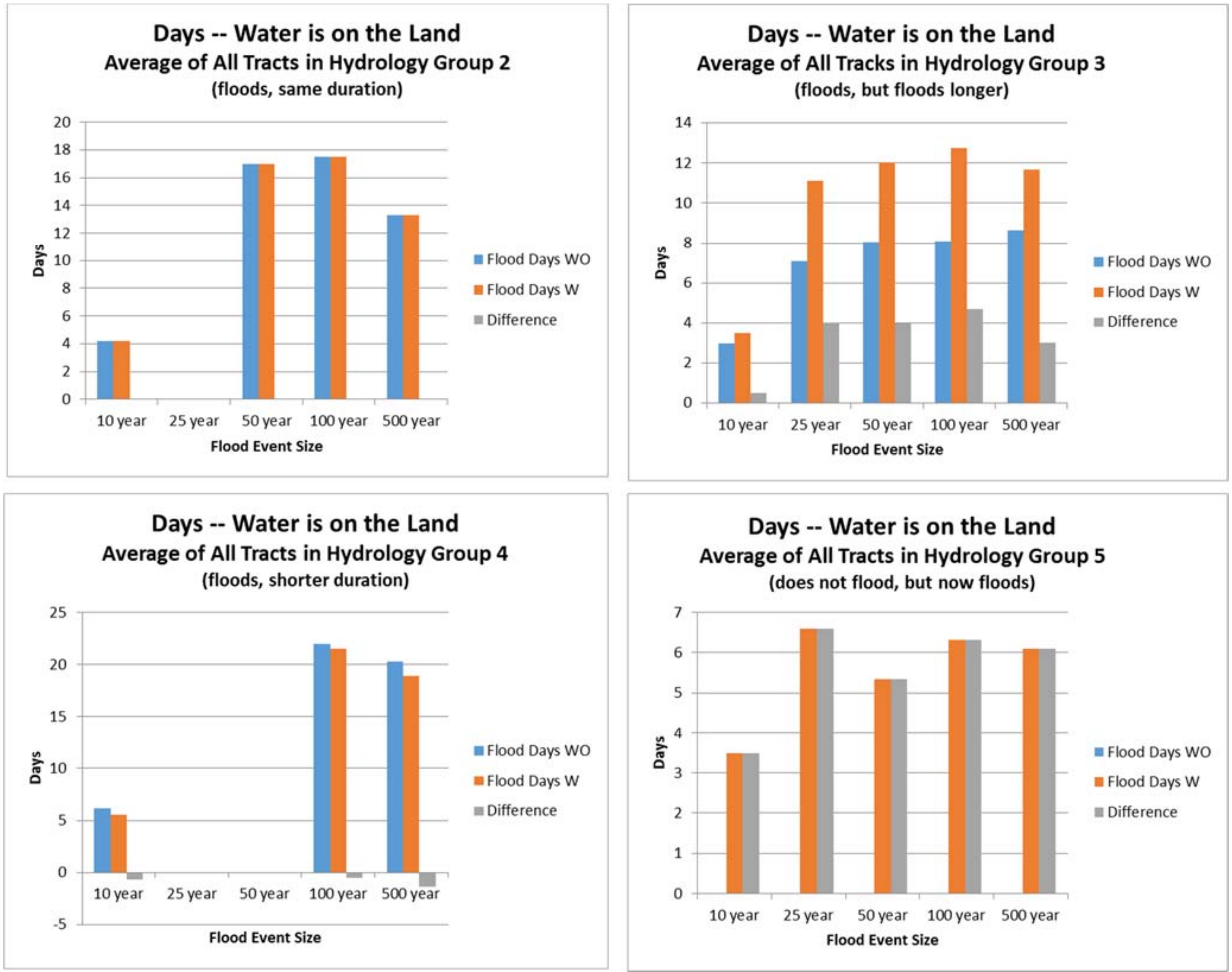
Appendix Table C26. Acreage of Storage Areas based on the Difference between With Diversion and Without Diversion scenarios, 50-year Flood Event, Measuring Days from Activation of Staging Area until the Effects of Flooding are over (Inundation plus Dry-down)					
Difference between With Diversion and Without Diversion, Inundation plus Dry-down	50-year Flood Event				
	Cass County	Clay County	Richland County	Wilkin County	Total
--- days ---	------------------- acres -------------------				
0	1,437	4,826	2,943	593	9,799
0.5	626				626
1	1,019		492		1,511
1.5	1,125		765		1,890
2	1,557		1,037	726	3,320
3	1,323		839		2,162
3.5	2,399	409	1,582	127	4,517
4	1,452		151		1,603
4.5	658	1,628			2,286
5	292	879			1,171
5.5	619				619
6		978			978
6.5		309			309
14		638			638
16		334		212	546
16.5		635			635
17		302	117	855	1,274
17.5			320	383	703
18	625		326		951
18.5		636			636
19	304	1,270			1,574
19.5		1,266			1,266
20		469	161		630
21		633			633
21.5	307				307
22	284	1,256			1,540
22.5		1,856			1,856
23.5	305				305

Source: FM Diversion Authority (2015).

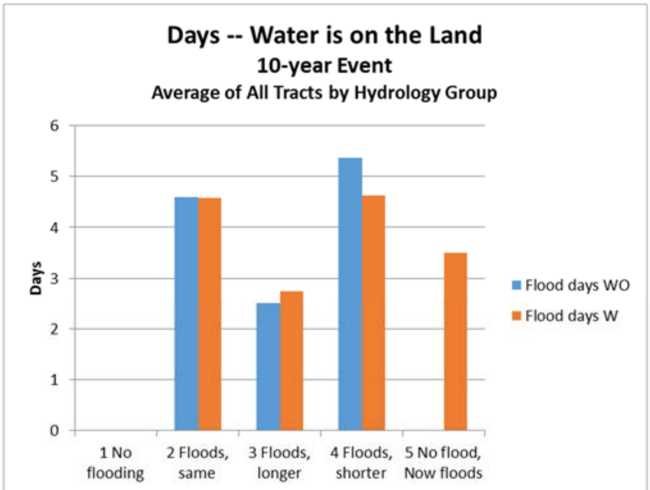
Appendix Table C27. Acreage of Storage Areas based on the Difference between With Diversion and Without Diversion scenarios, 100-year Flood Event, Measuring Days from Activation of Staging Area until the Effects of Flooding are over (Inundation plus Dry-down)					
Difference between With Diversion and Without Diversion, Inundation plus Dry-down	100-year Flood Event				
	Cass County	Clay County	Richland County	Wilkin County	Total
--- days ---	---------- acres ----------				
-0.5	808				808
0	626	1,276	2,642		4,544
0.5	408				408
1	1,736		492		2,228
1.5			1,802		1,802
2	1,262			938	2,200
2.5	295	638			933
3	929			455	1,384
3.5	1,383	409		400	2,192
4	1,174		839	383	2,396
4.5	1,980		324	127	2,431
5	873		1,258		2,131
5.5	404		301		705
6		1,628	312		1,940
6.5		879			879
7		1,287			1,287
8		1,225			1,225
9	305				305
15.5				593	593
17	629				629
18		179			179
18.5		1,274	117		1,391
19		636			636
19.5	625	635	646		1,906
20		939			939
20.5		328			328
21	304	1,466			1,770
21.5		1,266			1,266
22		1,739			1,739
23		633			633
24	591	1,256			1,847
24.5		631			631

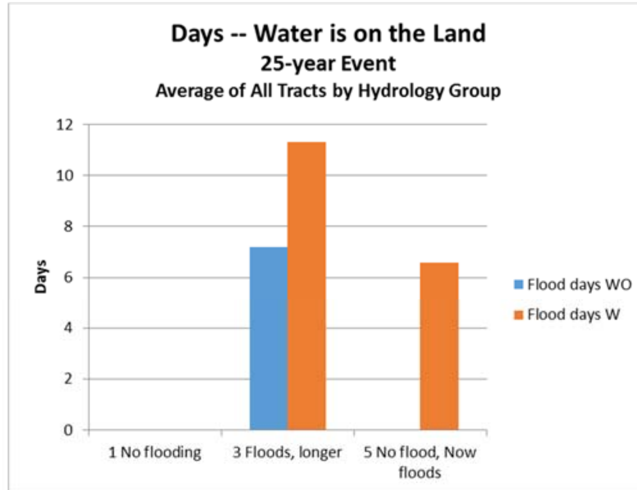
Source: FM Diversion Authority (2015).

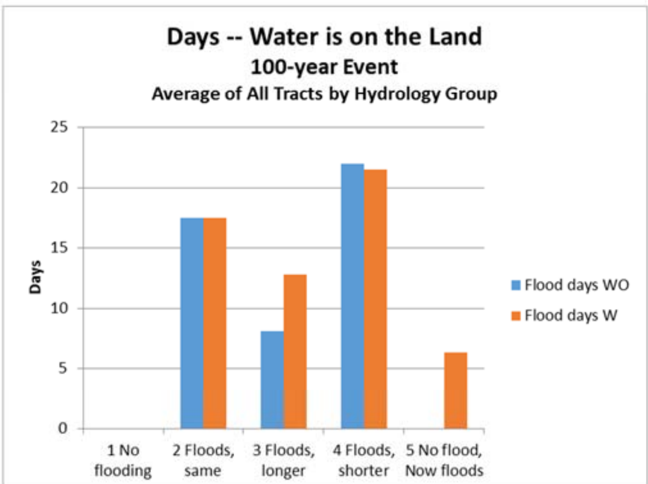
Appendix Table C28. Acreage of Storage Areas based on the Difference between With Diversion and Without Diversion scenarios, 500-year Flood Event, Measuring Days from Activation of Staging Area until the Effects of Flooding are over (Inundation plus Dry-down)					
Difference between With Diversion and Without Diversion, Inundation plus Dry-down	500-year Flood Event				
	Cass County	Clay County	Richland County	Wilkin County	Total
--- days ---	---------- acres ----------				
-3	631				631
-2.5	1,531				1,531
-2	611				611
-1.5	225				225
-1	2,070				2,070
-0.5	808	409			1,217
0	1,179		2,879		4,058
0.5			2,031		2,031
1	2,895		764	978	4,637
1.5	613	374		1,791	2,778
2	696	249	1,943	127	3,015
2.5	305	638	1,116		2,059
3	1,244	1,884			3,128
3.5		1,696			1,696
4	284	876			1,160
4.5		1,842			1,842
5	307				307
8		627			627
8.5		631			631
17		634			634
18		642			642
18.5	629				629
19		179			179
19.5		644			644
20.5		1,266			1,266
21.5	304				304
22		2,732			2,732
22.5		469			469
23		1,270			1,270
23.5		633			633
24.5		629			629
Source: FM Diversion Authority (2015).					

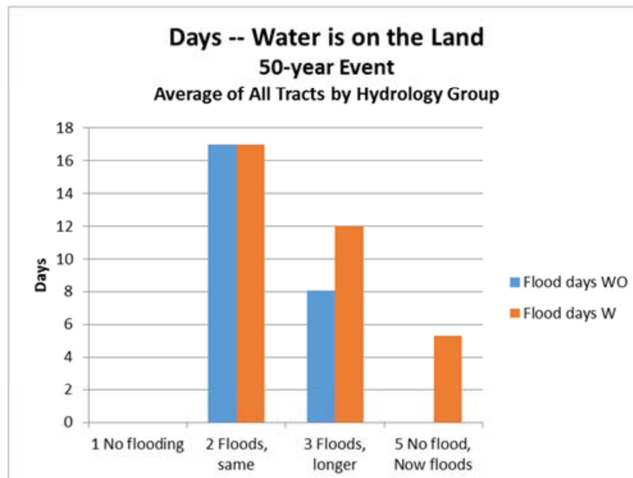


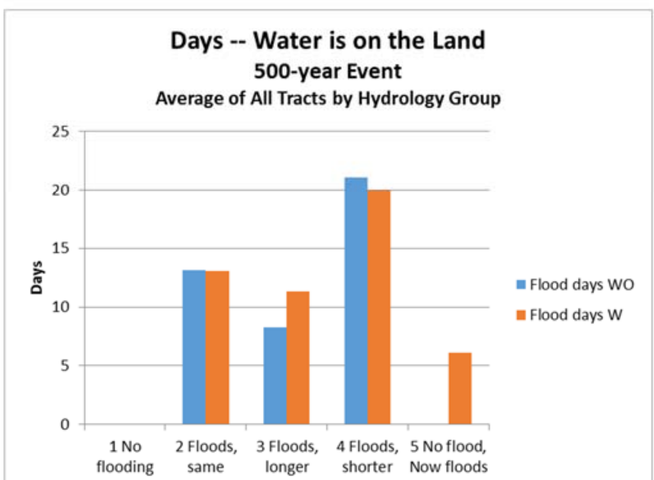
Appendix Figure C1. Duration of Inundation, by Hydrology Group and Size of Flood Event.
WO = Without Diversion W = With Diversion



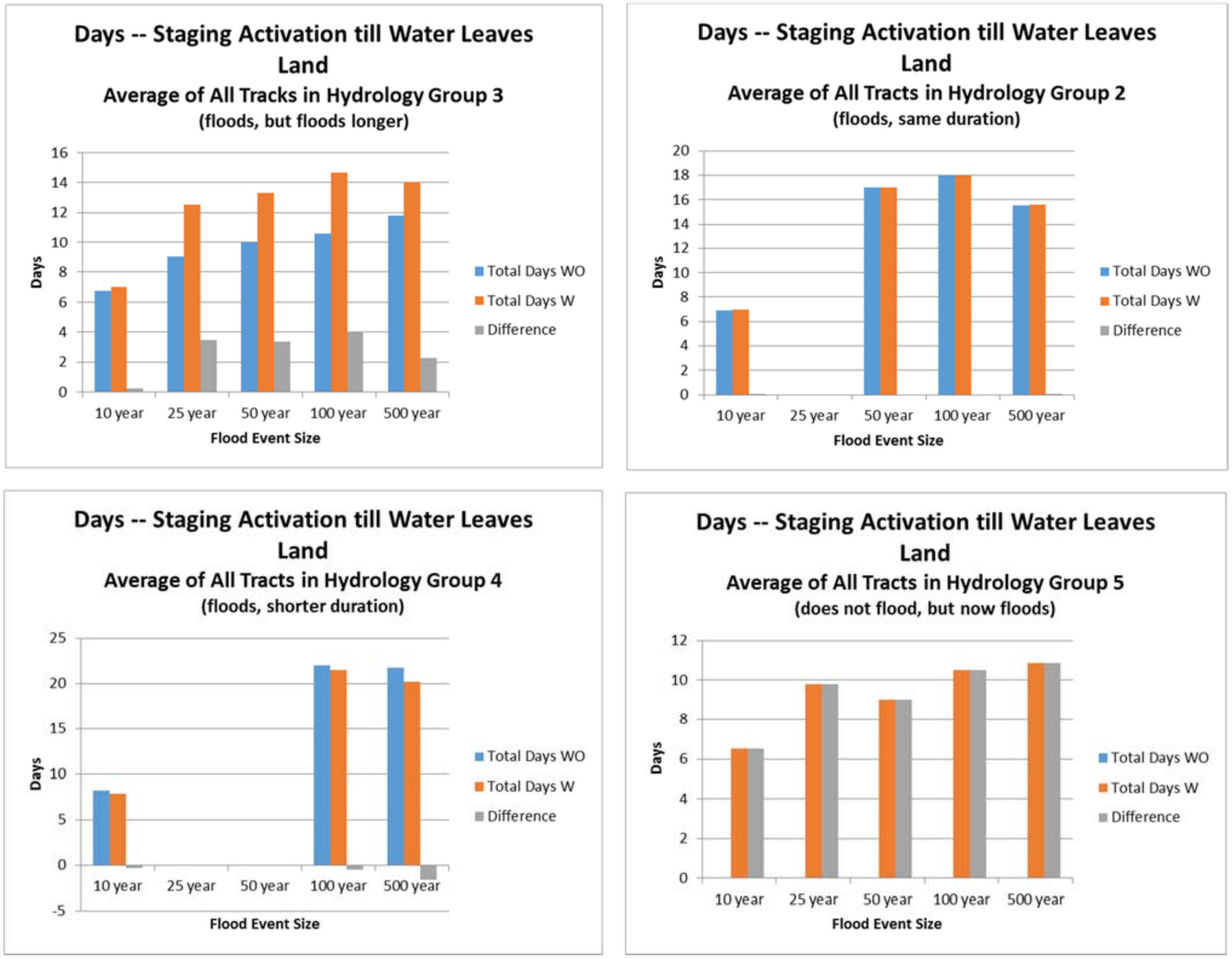






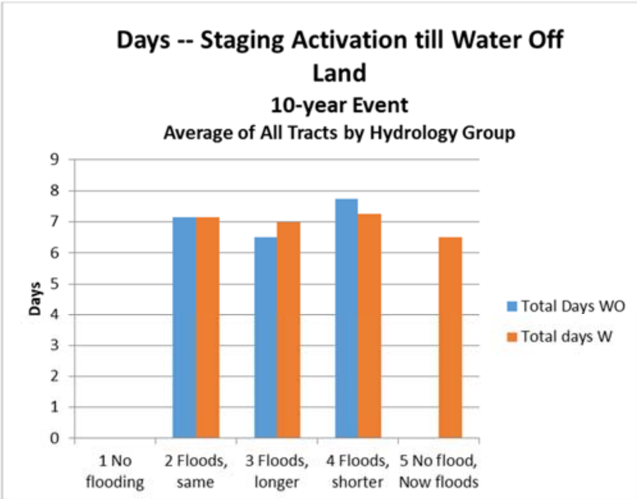


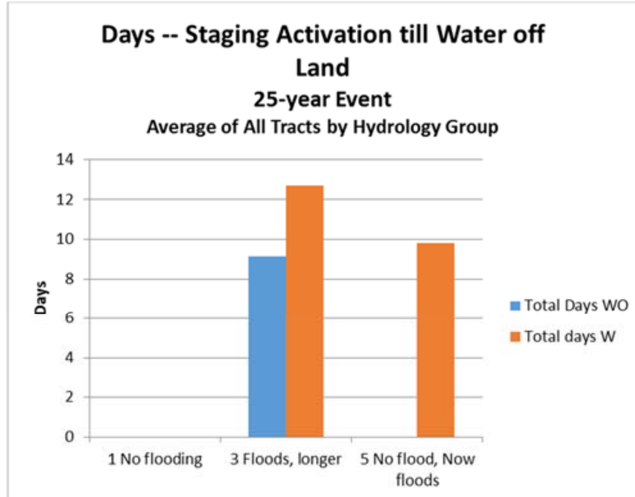
Appendix Figure C2. Duration of Inundation, by Hydrology Group and Size of Flood Event.
WO = Without Diversion W = With Diversion

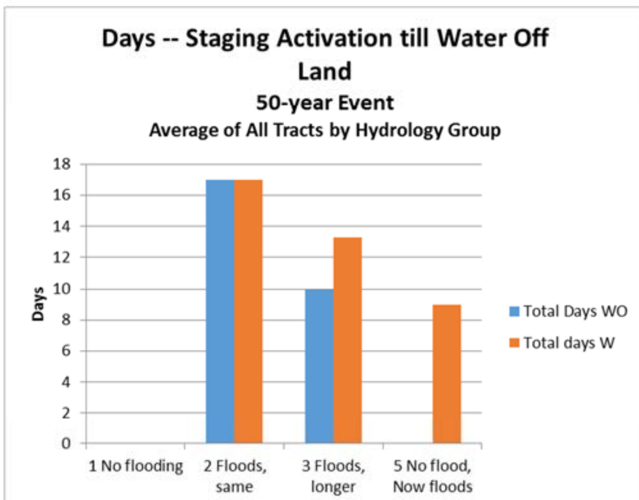


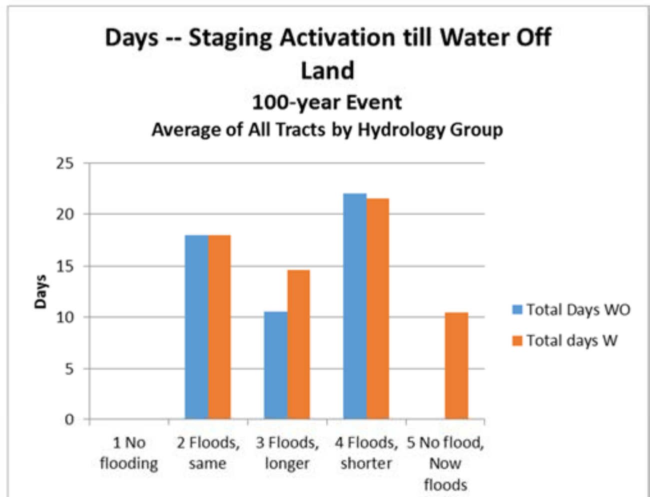
Appendix Figure C3. Days from Staging Activation until Water Leaves the Land, by Hydrology Group and Size of Flood Event.

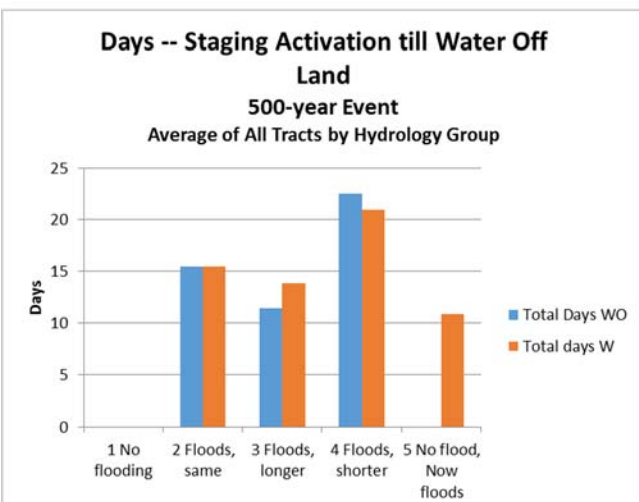
WO = Without Diversion W = With Diversion





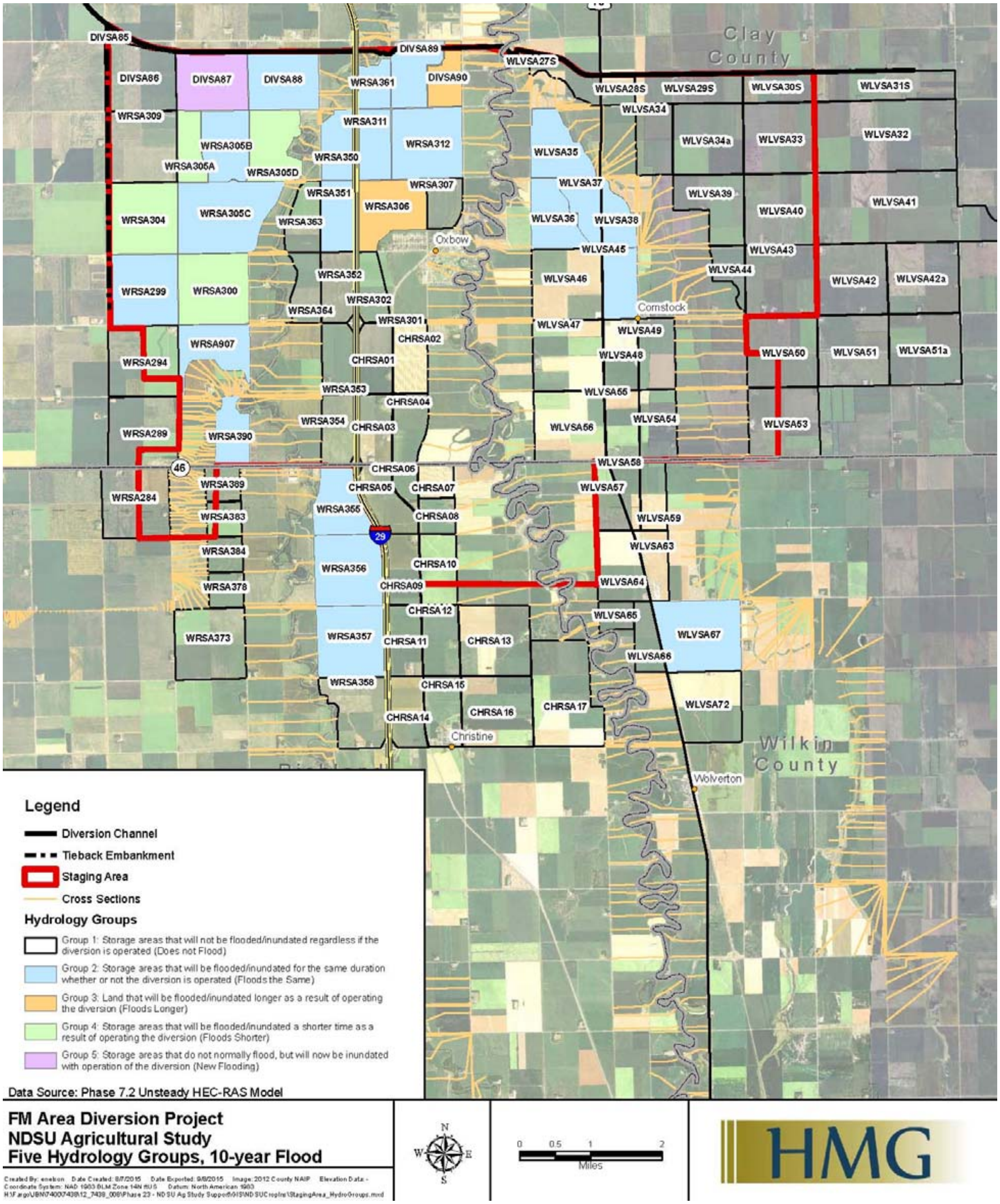




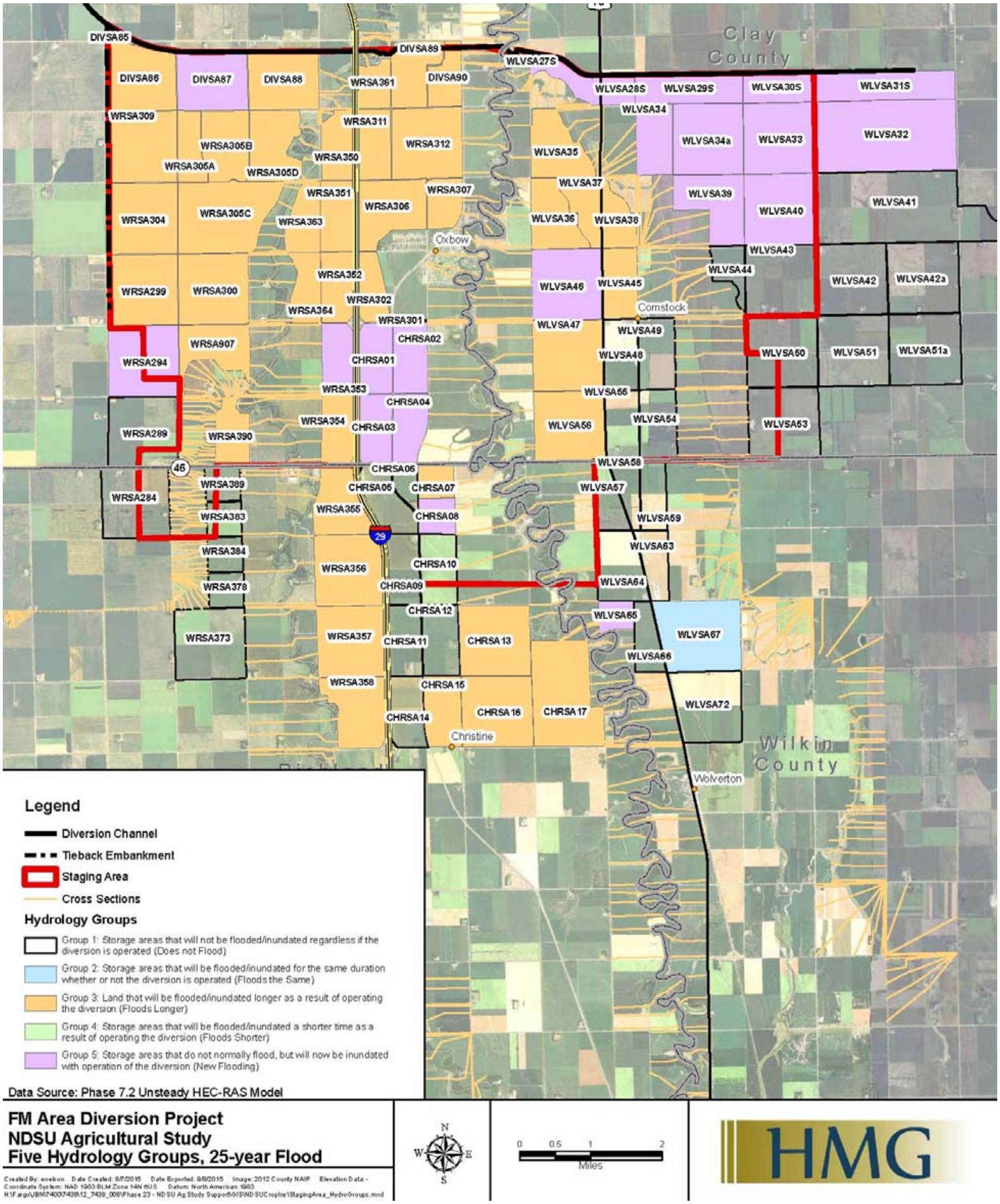


Appendix Figure C4. Days from Staging Activation until Water Leaves the Land, by Hydrology Group and Size of Flood Event.

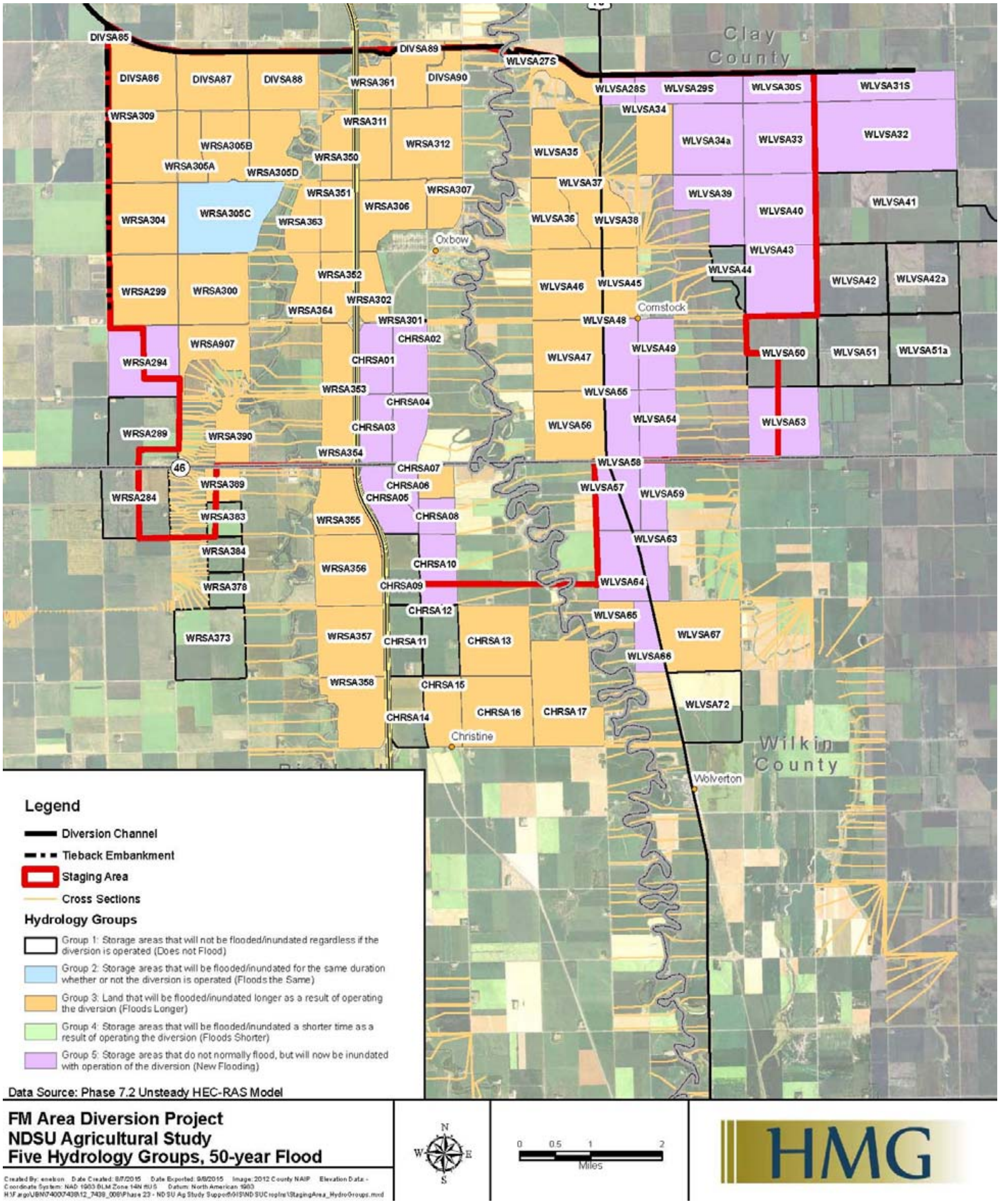
WO = Without Diversion W = With Diversion



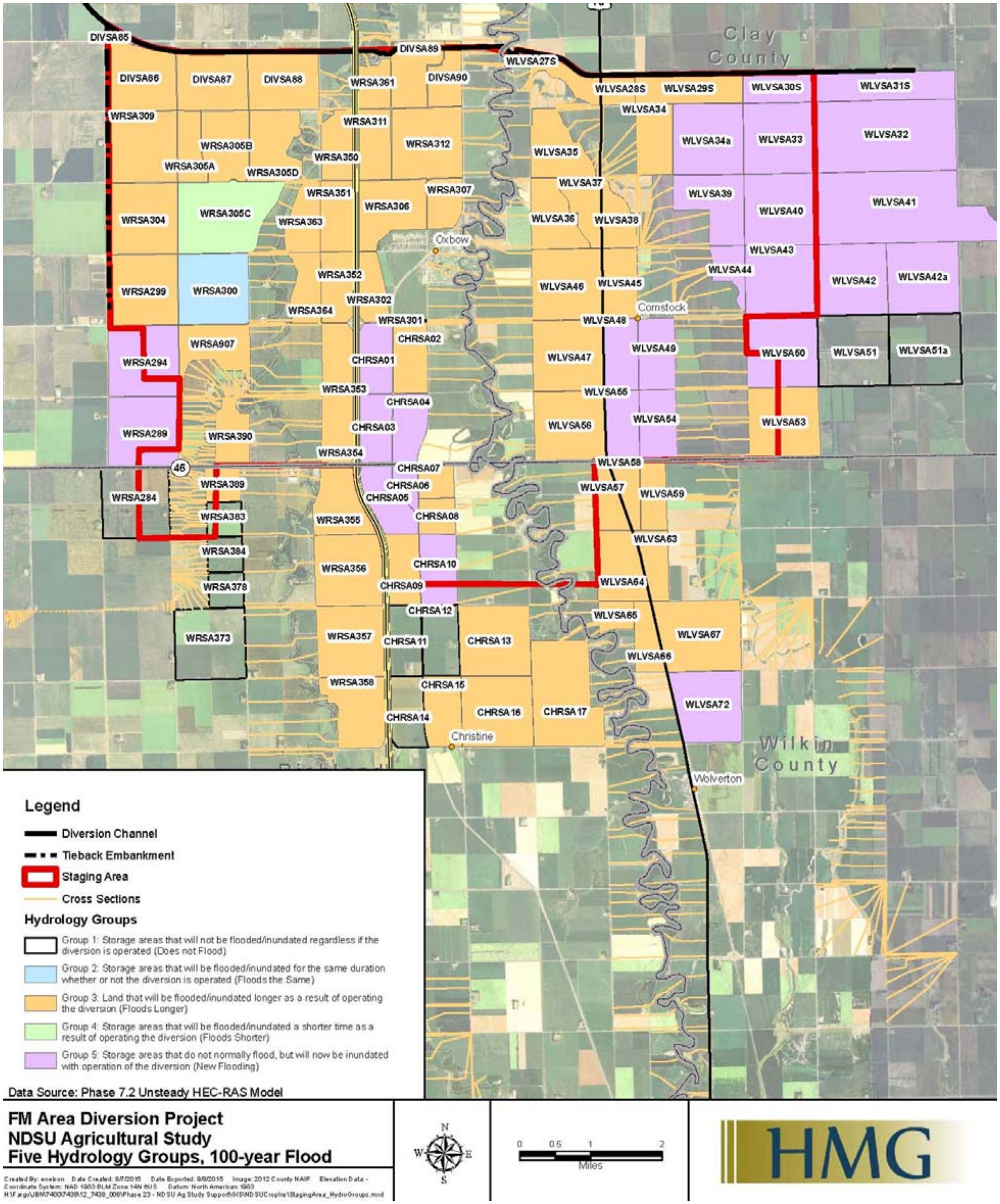
Appendix Figure C5. Hydrology Groups for Storage Areas, 10-year Flood Event



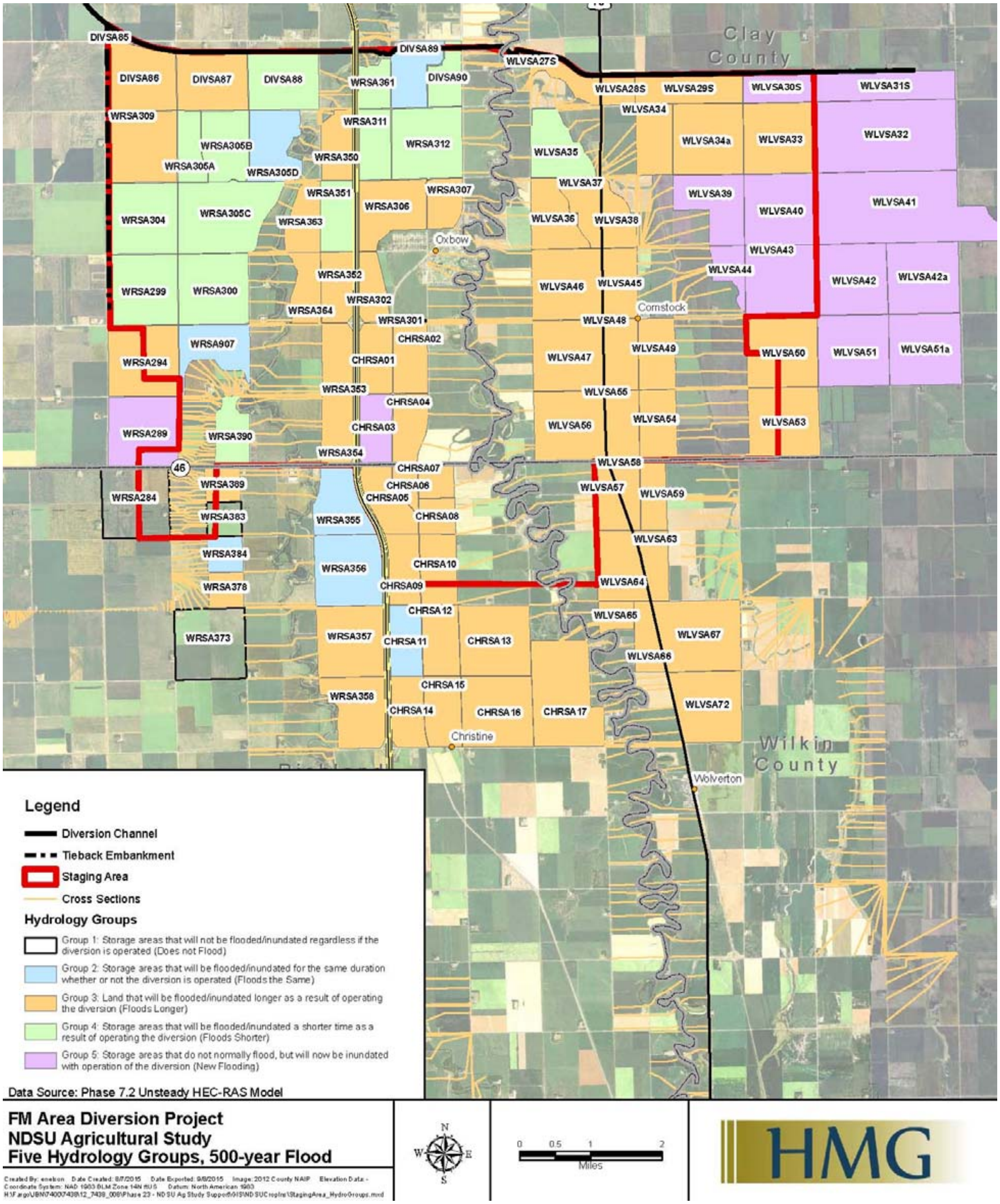
Appendix Figure C6. Hydrology Groups for Storage Areas, 25-year Flood Event



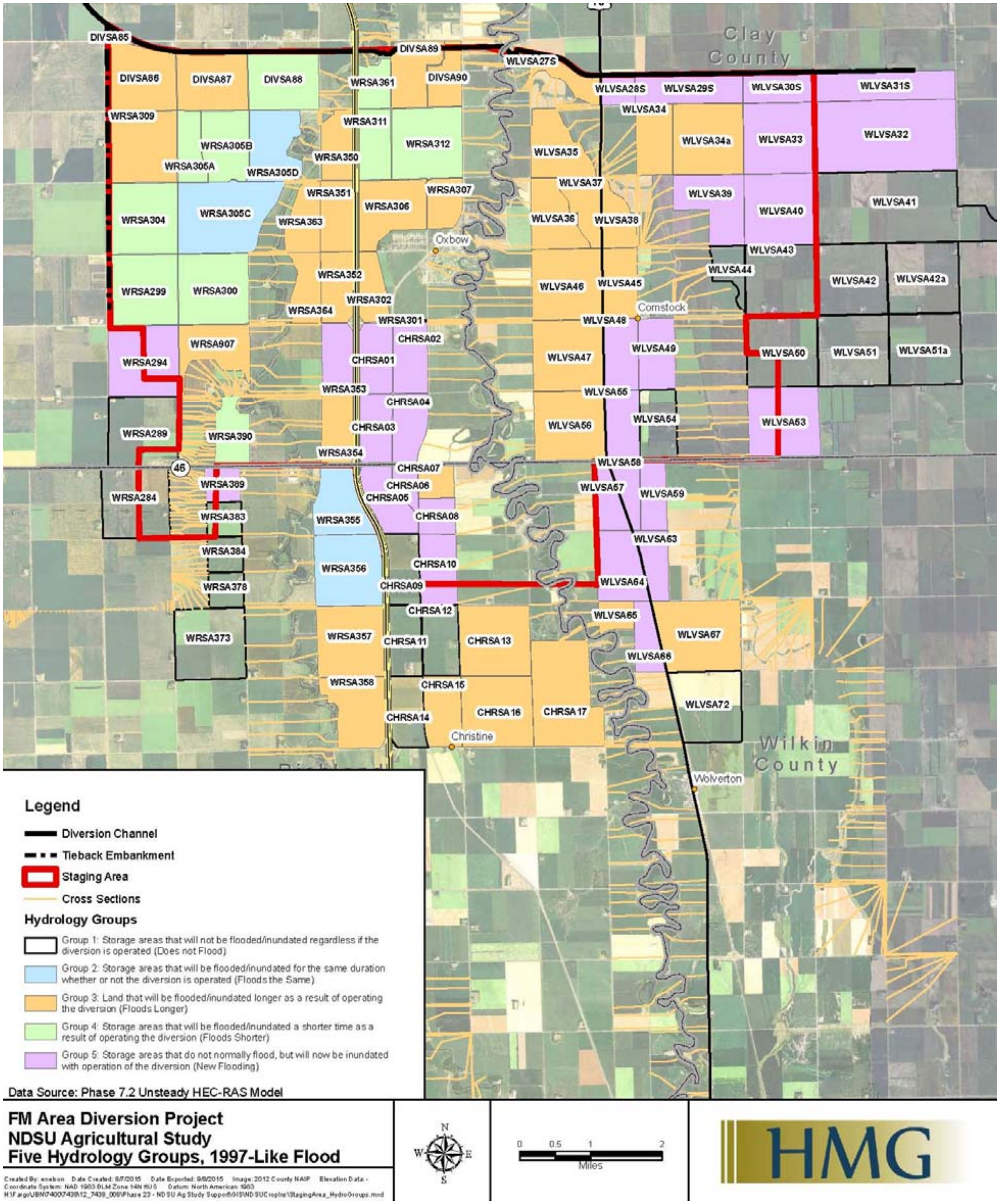
Appendix Figure C7. Hydrology Groups for Storage Areas, 50-year Flood Event



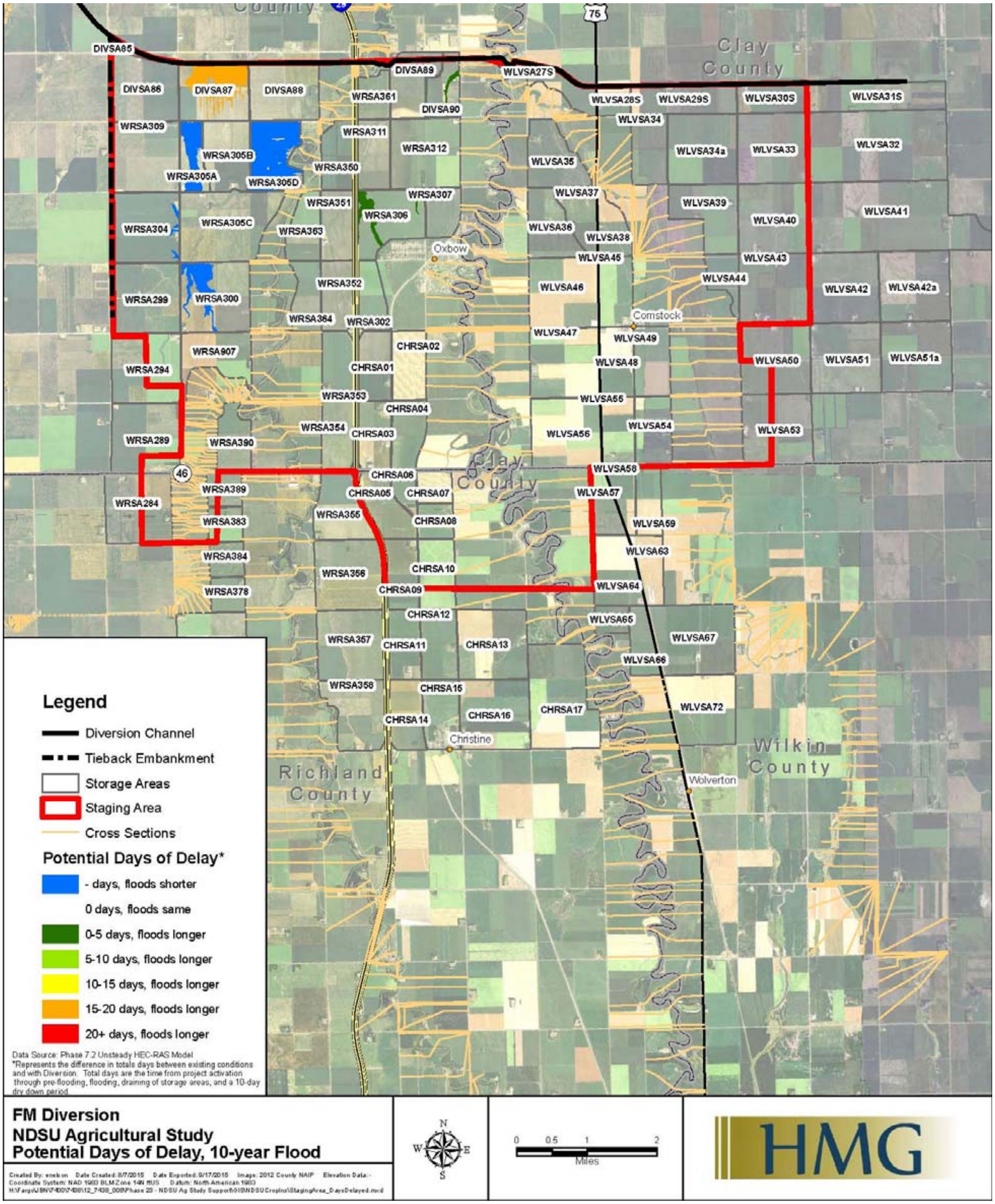
Appendix Figure C8. Hydrology Groups for Storage Areas, 100-year Flood Event



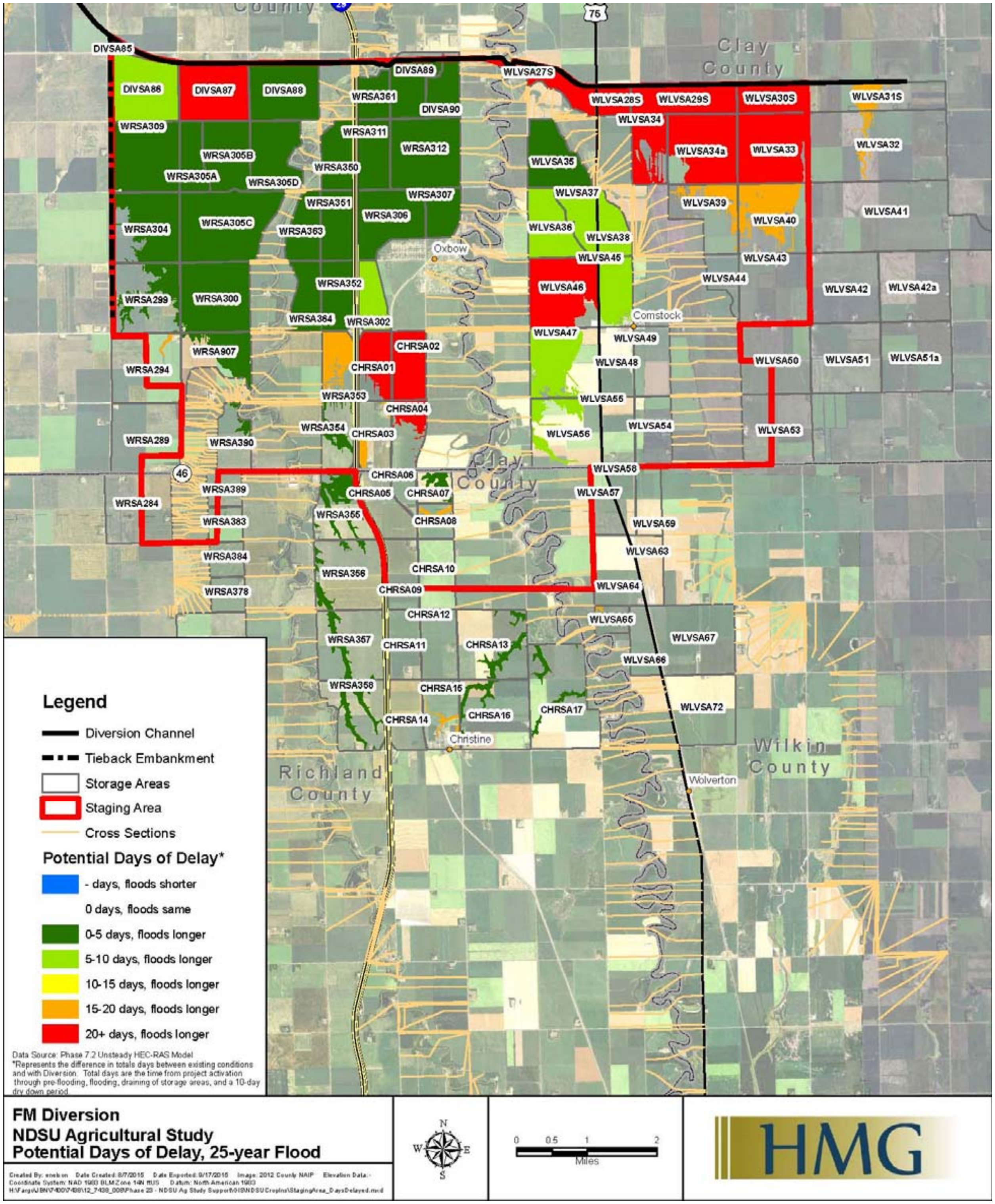
Appendix Figure C9. Hydrology Groups for Storage Areas, 500-year Flood Event



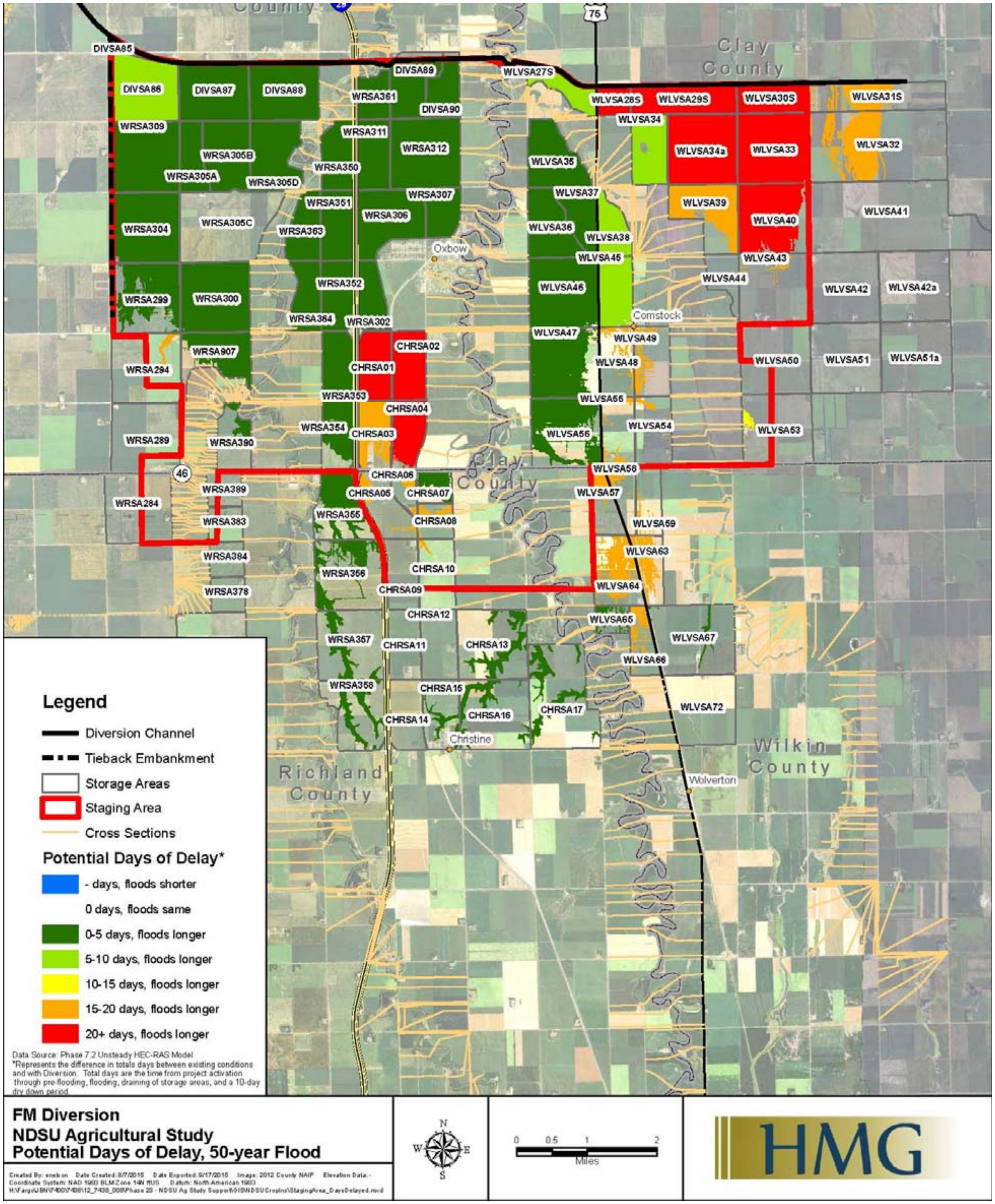
Appendix Figure C10. Hydrology Groups for Storage Areas, 1997-like Flood Event



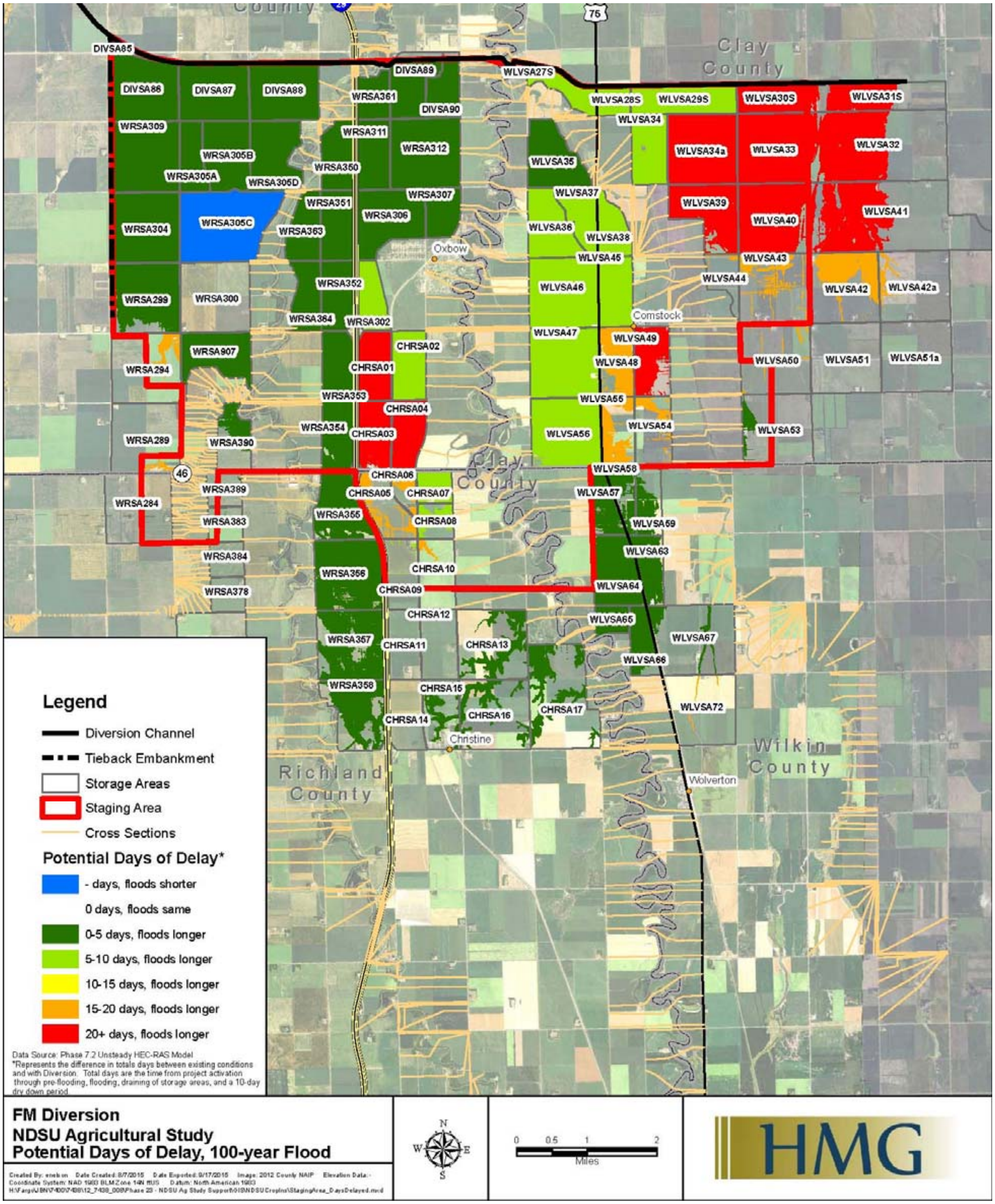
Appendix Figure C11. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 10-year Flood Event.



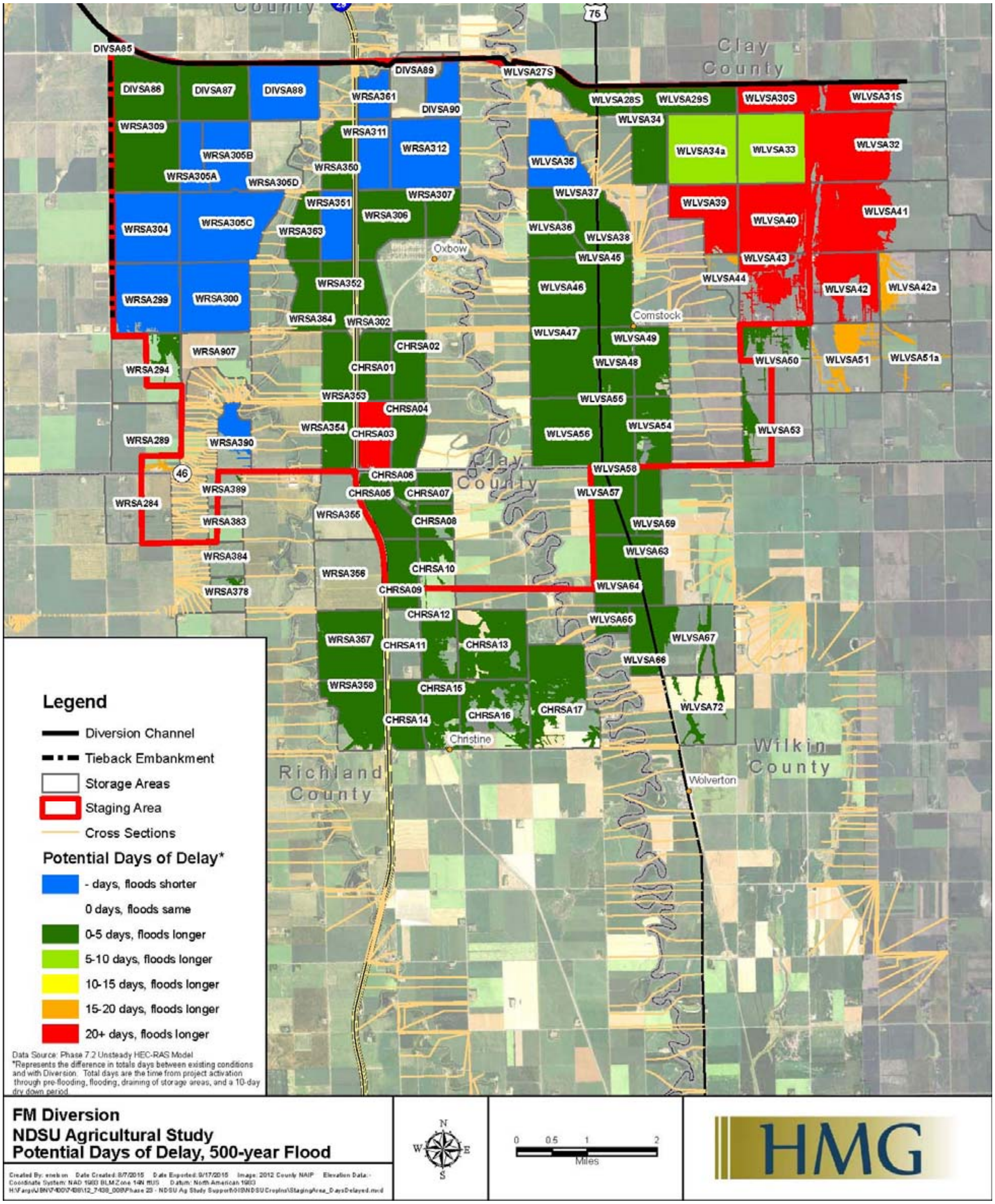
Appendix Figure C12. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 25-year Flood Event.



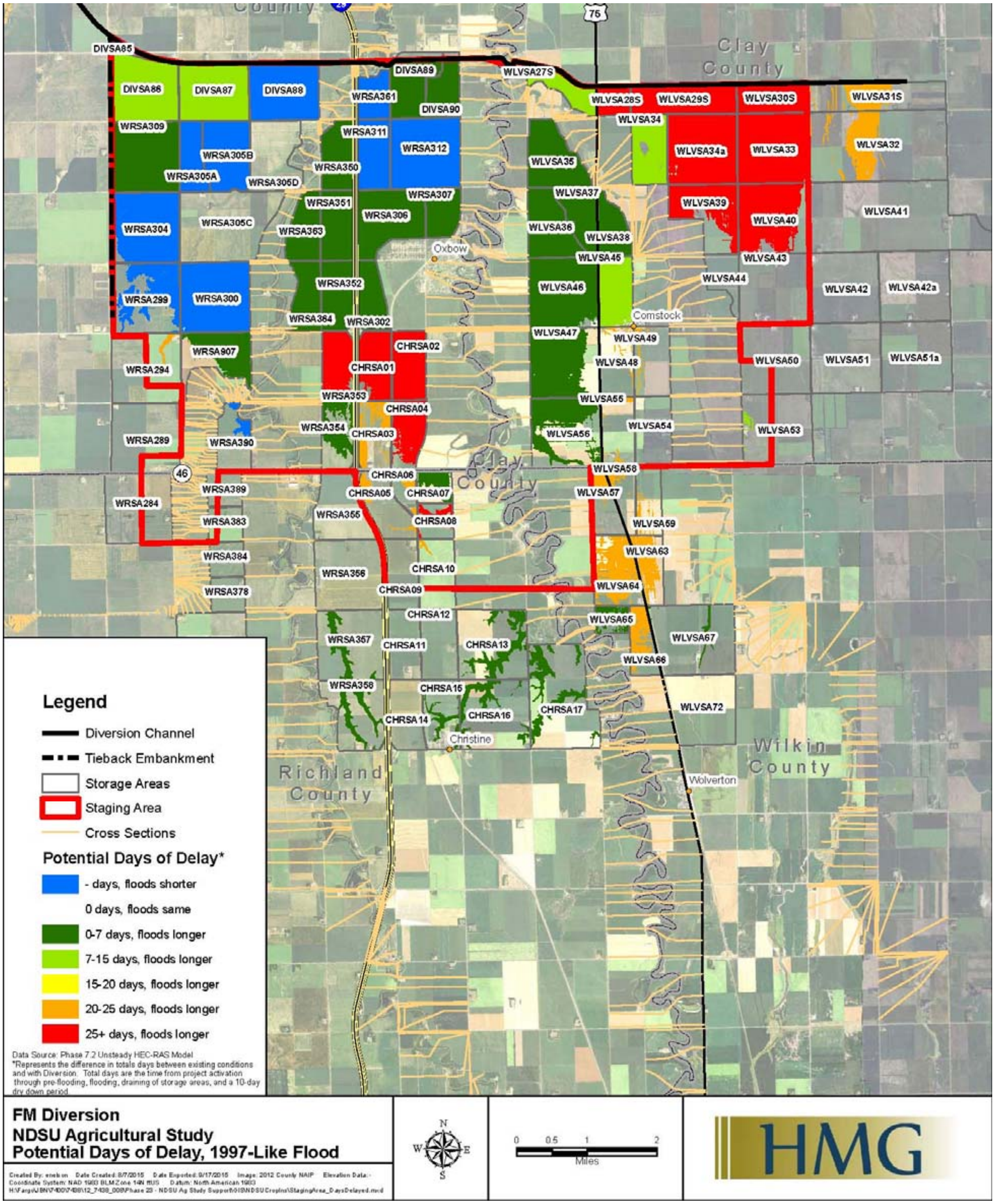
Appendix Figure C13. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 50-year Flood Event



Appendix Figure C14. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 100-year Flood Event.



Appendix Figure C15. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 500-year Flood Event.



Appendix Figure C16. Difference between Total Days (Time from Project Activation through pre-Flooding, Flooding, Draining of storage areas, and a 10-day Dry-down Period) With Diversion and Without Diversion, 1997-like Flood Event.

Appendix D
Acreage of Prevent Plant and Planted Acreage,
Clay and Wilkin Counties, Minnesota
Cass and Richland Counties, North Dakota
2009 through 2014

Appendix Table D1. Prevent Plant Acreage for Selected Crops, by County, FM Diversion Staging Area, 2009 through 2014						
Minnesota	2014	2013	2012	2011	2010	2009
Clay County						
Corn	10,811.9	1,093.1	0.0	4,433.5	1,457.0	5,097.7
Soybeans	2,673.6	613.6	111.9	1,933.1	360.9	1,634.2
Sugarbeets	0.0	0.0	0.0	3.0	0.0	0.0
Wheat	176.7	39.0	62.1	347.8	102.3	166.2
Total	13,662.1	1,745.8	174.0	6,717.4	1,920.2	6,898.1
Wilkin County						
Corn	11,575.2	4,174.7	0.0	1,281.2	1,500.3	5,702.3
Soybeans	3,963.2	1,330.5	0.0	916.2	234.4	1,857.0
Sugarbeets	0.0	28.3	0.0	0.0	0.0	103.5
Wheat	146.3	46.4	0.0	35.6	278.0	400.1
Total	15,684.7	5,579.9	0.0	2,233.0	2,012.7	8,062.9
Total MN Counties	29,346.8	7,325.7	174.0	8,950.4	3,932.9	14,961.0
North Dakota						
Cass County						
Corn	52,463.1	7,664.2	972.2	88,965.3	26,510.3	37,386.9
Soybeans	5,127.5	2,212.6	1,421.8	26,267.3	12,412.0	7,392.8
Sugarbeets	0.0	0.0	12.0	18.5	0.0	0.0
Wheat	275.5	107.4	172.7	7,107.9	1,540.0	1,192.1
Total	57,866.1	9,984.2	2,578.7	122,359.0	40,462.3	45,971.8
Richland County						
Corn	39,963.2	20,612.8	2,637.0	41,343.5	39,928.7	42,210.5
Soybeans	9,157.7	6,315.1	3,296.9	9,999.9	8,624.1	9,702.2
Sugarbeets	127.0	0.0	0.0	11.3	65.2	441.5
Wheat	353.0	197.9	310.6	1,594.4	1,280.7	1,693.7
Total	49,600.9	27,125.8	6,244.5	52,949.2	49,898.7	54,047.9
Total ND Counties	107,467.0	37,110.0	8,823.2	175,308.2	90,361.0	100,019.7
Total ND and MN	136,813.8	44,435.7	8,997.2	184,258.6	94,293.9	114,980.7
Source: Farm Service Agency (2015).						

Appendix Table D2. Total Crop Acreage for Selected Crops, by County, FM Diversion Staging Area, 2009 through 2014						
Minnesota	2014	2013	2012	2011	2010	2009
Clay County						
Corn	110,676	141,851	129,422	111,798	92,161	86,676
Soybeans	194,051	168,041	164,666	167,719	182,129	184,688
Sugarbeets	36,674	42,012	41,839	45,555	40,365	41,979
Wheat	53,090	55,707	65,231	80,106	86,514	87,039
Total	394,491	407,611	401,157	405,178	401,168	400,382
Wilkin County						
Corn	105,855	126,792	110,744	92,841	73,279	76,680
Soybeans	182,419	154,460	162,618	154,512	171,739	160,379
Sugarbeets	50,491	56,154	53,378	56,115	53,340	54,581
Wheat	64,015	70,309	78,659	99,705	95,973	103,751
Total	402,779	407,716	405,399	403,172	394,332	395,391
Total MN Counties	797,270	815,327	806,556	808,350	795,499	795,774
North Dakota						
Cass County						
Corn	266,761	363,703	350,635	290,972	252,399	234,150
Soybeans	533,459	462,041	455,560	513,141	519,625	543,732
Sugarbeets	20,198	18,920	17,971	17,297	14,905	16,255
Wheat	79,630	71,083	84,010	97,061	114,098	100,868
Total	900,048	915,748	908,176	918,470	901,027	895,004
Richland County						
Corn	274,743	326,060	300,022	304,519	277,981	277,360
Soybeans	354,999	305,090	311,722	300,885	329,152	321,039
Sugarbeets	27,134	29,381	29,673	31,140	30,703	31,399
Wheat	49,119	44,968	58,092	69,505	67,588	79,256
Total	705,995	705,499	699,509	706,049	705,424	709,054
Total ND Counties	1,606,043	1,621,247	1,607,685	1,624,519	1,606,451	1,604,058
Total MN and ND	2,403,313	2,436,574	2,414,241	2,432,870	2,401,951	2,399,831

Note: Total crop acreage is the sum of all planted acreage and prevent plant acreage.
Source: Farm Service Agency (2015).

Appendix Table D3. Percentage of Total Crop Acreage that was Prevent Plant for Selected Crops, by County, FM Diversion Staging Area, 2009 through 2014						
Minnesota	2014	2013	2012	2011	2010	2009
Clay County	---------------------------------------%---------------------------------------					
Corn	9.77	0.77	0.00	3.97	1.58	5.88
Soybeans	1.38	0.37	0.07	1.15	0.20	0.88
Sugarbeets	0.00	0.00	0.00	0.01	0.00	0.00
Wheat	0.33	0.07	0.10	0.43	0.12	0.19
Total	3.46	0.43	0.04	1.66	0.48	1.72
Wilkin County						
Corn	10.93	3.29	0.00	1.38	2.05	7.44
Soybeans	2.17	0.86	0.00	0.59	0.14	1.16
Sugarbeets	0.00	0.05	0.00	0.00	0.00	0.19
Wheat	0.23	0.07	0.00	0.04	0.29	0.39
Total	3.89	1.37	0.00	0.55	0.51	2.04
Total MN Counties	3.68	0.90	0.02	1.11	0.49	1.88
North Dakota						
Cass County						
Corn	19.67	2.11	0.28	30.58	10.50	15.97
Soybeans	0.96	0.48	0.31	5.12	2.39	1.36
Sugarbeets	0.00	0.00	0.07	0.11	0.00	0.00
Wheat	0.35	0.15	0.21	7.32	1.35	1.18
Total	6.43	1.09	0.28	13.32	4.49	5.14
Richland County						
Corn	14.55	6.32	0.88	13.58	14.36	15.22
Soybeans	2.58	2.07	1.06	3.32	2.62	3.02
Sugarbeets	0.47	0.00	0.00	0.04	0.21	1.41
Wheat	0.72	0.44	0.53	2.29	1.89	2.14
Total	7.03	3.84	0.89	7.50	7.07	7.62
Total ND Counties	6.69	2.29	0.55	10.79	5.62	6.24
Total MN and ND	5.69	1.82	0.37	7.57	3.93	4.79
Source: Farm Service Agency (2015).						

Appendix E

Example of Decision Criteria and Analysis of Producer-level Economics of Prevent Planting versus Switching Crops

2014

Prevented Planting (PP) and Planting Comparison, per Acre, 2014

Developed by Andrew Swenson, NDSU Extension Service, Revised May 12, 2014

PP Crop		Spring Wheat	Instructions and Comments:
APH		38	Actual Production History (APH) yield for crop insurance
Crop Insurance Coverage Level		70%	
PP Coverage		60%	
Insured Price for PP		$ 6.510	
PP Indemnity Payment		$ 103.90	
Seed for cover crop	$ 7.00		Don't include 'sunk' costs such as land, mach. depre., and crop insurance
Chemicals	$ 6.00		premiums that would be the same regardless of the PP decision.
Fuel & Lube	$ 8.00		
Repairs	$ 7.50		
Custom work	$ -		
Other	$ -		
PP Land Maintenance		$ 28.50	
PP Indemnity - Maintenance Costs		$ 75.40	Partial Budget of Prevented Planting
			(PP indemnity payment less direct costs of maintaining idled land.)

Crop, if Planted		Soybean	Enter any crop to compare with the PP situation in the above table.
APH		28	
Policy		Revenue	
Crop Insurance Coverage Level		70%	
Crop Insurance Base Price		$ 11.360	Projected (Spring) price if Revenue or Yield Policy, or APH insured price
Revenue Ins. Harvest Price est.		$ 12.000	If you have a Revenue policy, enter 'Harvest Price.' Enter 0 if APH or Yield policy.
No. of days crop is planted late		3	**No. of days after its "Final Planting Date" that this crop was planted.**[1]
Expected Yield		22	**Estimated actual 2014 yield. Try different numbers to see impact on analysis.**
Expected Market Price		$ 11.20	**Estimated cash sales price of 2014 production.**
Expected Crop Sale Revenue		$ 246.40	
Expected Crop Ins. Indemnity		$ -	
Seed	$ 69.00		Don't include 'sunk' costs such as land, mach. depre., and crop insurance
Chemicals	$ 20.00		premiums that would be the same regardless of the PP decision.
Fertilizer	$ 15.00		Note: do not include cost of fertilizer which was applied prior to the PP decision
Fuel & Lube	$ 14.50		because it would be a 'sunk' cost.
Repairs	$ 15.00		
Drying			
Custom Work			
Other			
Costs, planting through harvest		$ 133.50	
Revenue - Costs, planting thru harv.		$ 112.90	Partial Budget of Planting (Crop sales & crop ins. payments - marginal costs)

Gain (Loss) from Prevent Planting relative to Planting	**$ (37.50)**	A positive number indicates a greater return per acre from PP than for seeding. A (negative) number shows loss from PP relative to planting the crop.

Appendix Figure E1. Sample Framework for Determining Producer-level Economics of Switching Crop Acreage versus Prevent Plant.

Source: Swenson (2014b).

Appendix F
Target Crop Yields, Estimated Yield Declines, and Gross Revenue per Acre by Planting Date
Cass and Richland Counties, North Dakota
Clay and Wilkin Counties, Minnesota

Appendix Table F1. Target Crop Yields, Estimated Yield Declines, and Gross Revenue per Acre by Planting Date, Cass County, North Dakota								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
4/15	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/16	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/17	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/18	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/19	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/20	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/21	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/22	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/23	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/24	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/25	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/26	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/27	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/28	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/29	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
4/30	142.0	$618.31			58.0	$398.44	22.1	$1,285.06
5/1	142.0	$618.31	40.2	$438.04	57.0	$391.78	22.1	$1,285.06
5/2	141.3	$615.18	40.2	$438.04	56.1	$385.24	21.9	$1,273.18
5/3	140.6	$612.09	40.2	$438.04	55.1	$378.81	21.7	$1,261.30
5/4	139.9	$608.99	40.2	$438.04	54.2	$372.48	21.5	$1,249.42
5/5	139.2	$605.90	40.2	$438.04	53.3	$366.26	21.3	$1,237.55
5/6	138.5	$602.81	40.2	$438.04	52.4	$360.15	21.1	$1,225.67
5/7	137.7	$599.72	40.2	$438.04	51.5	$354.13	20.9	$1,213.79
5/8	137.0	$596.63	40.2	$438.04	50.7	$348.22	20.7	$1,201.91
5/9	136.3	$593.54	40.2	$438.04	49.8	$342.40	20.4	$1,190.04
5/10	135.6	$590.45	40.2	$438.04	49.0	$336.68	20.2	$1,178.16
5/11	134.1	$583.80	40.2	$438.04	48.2	$331.06	20.0	$1,166.28
5/12	132.6	$577.15	40.2	$438.04	47.4	$325.53	19.8	$1,154.40
5/13	131.0	$570.51	40.2	$438.04	46.6	$320.10	19.6	$1,142.53
5/14	129.5	$563.86	40.2	$438.04	45.8	$314.75	19.4	$1,130.65
5/15	128.0	$557.21	40.2	$438.04	45.0	$309.49	19.2	$1,118.77
5/16	126.5	$550.57	40.2	$438.04	44.3	$304.33	19.0	$1,106.89
5/17	124.9	$543.92	40.2	$438.04	43.5	$299.24	18.8	$1,095.02
5/18	123.4	$537.27	40.2	$438.04	42.8	$294.25	18.6	$1,083.14
5/19	121.9	$530.63	40.2	$438.04	42.1	$289.33	18.4	$1,071.26
5/20	120.3	$523.98	40.2	$438.04	41.4	$284.50	18.2	$1,059.38
5/21	117.7	$512.39	40.0	$435.85	40.7	$279.75	18.0	$1,047.50
5/22	115.0	$500.80	39.8	$433.67	40.0	$275.08	17.8	$1,035.63
5/23	112.4	$489.20	39.6	$431.50	39.4	$270.48	17.6	$1,023.75
5/24	109.7	$477.61	39.4	$429.35	38.7	$265.97	17.4	$1,011.87
5/25	107.0	$466.02	39.2	$427.20	38.1	$261.52	17.2	$999.99
- continued -								

Appendix Table F1. Continued								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
5/26	104.4	$454.43	39.0	$425.06	37.4	$257.16	17.0	$988.12
5/27	101.7	$442.83	38.8	$422.94	36.8	$252.86	16.8	$976.24
5/28	99.0	$431.24	38.6	$420.82	36.2	$248.64	16.6	$964.36
5/29	96.4	$419.65	38.4	$418.72	35.6	$244.49	16.4	$952.48
5/30	93.7	$408.06	38.2	$416.63	35.0	$240.40	16.2	$940.61
5/31	91.1	$396.46	38.0	$414.54	34.4	$236.39	16.0	$928.73
6/1	88.4	$384.87	37.8	$412.47	33.8	$232.44	15.8	$916.85
6/2			37.6	$410.41			15.5	$904.97
6/3			37.5	$408.36			15.3	$893.10
6/4			37.3	$406.31			15.1	$881.22
6/5			37.1	$404.28			14.9	$869.34
6/6			36.9	$402.26			14.7	$857.46
6/7			36.7	$400.25			14.5	$845.59
6/8			36.5	$398.25			14.3	$833.71
6/9			36.3	$396.26			14.1	$821.83
6/10			36.2	$394.28			13.9	$809.95
6/11			36.0	$392.31			13.7	$798.08
6/12								

Appendix Table F2. Target Crop Yields, Estimated Yield Declines, and Gross Revenue per Acre by Planting Date, Richland County, North Dakota								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
4/15	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/16	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/17	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/18	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/19	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/20	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/21	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/22	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/23	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/24	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/25	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/26	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/27	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/28	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/29	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
4/30	152.9	$665.81			58.9	$404.69	24.6	$1,434.05
5/1	152.9	$665.81	44.0	$479.36	57.9	$397.93	24.6	$1,434.05
5/2	152.2	$662.48	44.0	$479.36	56.9	$391.29	24.4	$1,422.17
5/3	151.4	$659.16	44.0	$479.36	56.0	$384.75	24.2	$1,410.29
5/4	150.6	$655.83	44.0	$479.36	55.1	$378.33	24.0	$1,398.42
5/5	149.9	$652.50	44.0	$479.36	54.1	$372.01	23.8	$1,386.54
5/6	149.1	$649.17	44.0	$479.36	53.2	$365.80	23.6	$1,374.66
5/7	148.3	$645.84	44.0	$479.36	52.3	$359.69	23.4	$1,362.78
5/8	147.6	$642.51	44.0	$479.36	51.5	$353.68	23.2	$1,350.91
5/9	146.8	$639.18	44.0	$479.36	50.6	$347.78	23.0	$1,339.03
5/10	146.0	$635.85	44.0	$479.36	49.8	$341.97	22.8	$1,327.15
5/11	144.4	$628.69	44.0	$479.36	48.9	$336.26	22.6	$1,315.27
5/12	142.8	$621.54	44.0	$479.36	48.1	$330.64	22.4	$1,303.39
5/13	141.1	$614.38	44.0	$479.36	47.3	$325.12	22.2	$1,291.52
5/14	139.5	$607.22	44.0	$479.36	46.5	$319.69	22.0	$1,279.64
5/15	137.8	$600.06	44.0	$479.36	45.7	$314.35	21.8	$1,267.76
5/16	136.2	$592.91	44.0	$479.36	45.0	$309.10	21.6	$1,255.88
5/17	134.5	$585.75	44.0	$479.36	44.2	$303.94	21.4	$1,244.01
5/18	132.9	$578.59	44.0	$479.36	43.5	$298.86	21.2	$1,232.13
5/19	131.2	$571.43	44.0	$479.36	42.8	$293.87	21.0	$1,220.25
5/20	129.6	$564.28	44.0	$479.36	42.0	$288.97	20.8	$1,208.37
5/21	126.7	$551.79	43.8	$476.96	41.3	$284.14	20.6	$1,196.50
5/22	123.9	$539.31	43.5	$474.58	40.7	$279.39	20.4	$1,184.62
5/23	121.0	$526.83	43.3	$472.21	40.0	$274.73	20.2	$1,172.74
5/24	118.1	$514.34	43.1	$469.85	39.3	$270.14	19.9	$1,160.86
5/25	115.3	$501.86	42.9	$467.50	38.7	$265.63	19.7	$1,148.99
- continued -								

Appendix Table F2. Continued								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
5/26	112.4	$489.37	42.7	$465.16	38.0	$261.19	19.5	$1,137.11
5/27	109.5	$476.89	42.5	$462.83	37.4	$256.83	19.3	$1,125.23
5/28	106.7	$464.41	42.2	$460.52	36.7	$252.54	19.1	$1,113.35
5/29	103.8	$451.92	42.0	$458.22	36.1	$248.32	18.9	$1,101.48
5/30	100.9	$439.44	41.8	$455.93	35.5	$244.18	18.7	$1,089.60
5/31	98.1	$426.95	41.6	$453.65	34.9	$240.10	18.5	$1,077.72
6/1	95.2	$414.47	41.4	$451.38	34.4	$236.09	18.3	$1,065.84
6/2			41.2	$449.12			18.1	$1,053.97
6/3			41.0	$446.87			17.9	$1,042.09
6/4			40.8	$444.64			17.7	$1,030.21
6/5			40.6	$442.42			17.5	$1,018.33
6/6			40.4	$440.21			17.3	$1,006.46
6/7			40.2	$438.00			17.1	$994.58
6/8			40.0	$435.81			16.9	$982.70
6/9			39.8	$433.63			16.7	$970.82
6/10			39.6	$431.47			16.5	$958.95
6/11			39.4	$429.31			16.3	$947.07
6/12								

Appendix Table F3. Target Crop Yields, Estimated Yield Declines, and Gross Revenue per Acre by Planting Date, Clay County, Minnesota								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
4/15	153.7	$669.21			63.9	$439.12	26.6	$1,545.21
4/16	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/17	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/18	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/19	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/20	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/21	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/22	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/23	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/24	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/25	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/26	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/27	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/28	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/29	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
4/30	153.7	$668.68			63.9	$439.12	26.6	$1,545.21
5/1	153.7	$668.68	45.5	$495.50	62.8	$431.79	26.6	$1,545.21
5/2	153.0	$665.34	45.5	$495.50	61.8	$424.58	26.3	$1,533.33
5/3	152.2	$662.00	45.5	$495.50	60.8	$417.49	26.1	$1,521.45
5/4	151.4	$658.65	45.5	$495.50	59.7	$410.51	25.9	$1,509.58
5/5	150.6	$655.31	45.5	$495.50	58.7	$403.66	25.7	$1,497.70
5/6	149.9	$651.96	45.5	$495.50	57.8	$396.92	25.5	$1,485.82
5/7	149.1	$648.62	45.5	$495.50	56.8	$390.29	25.3	$1,473.94
5/8	148.3	$645.28	45.5	$495.50	55.8	$383.77	25.1	$1,462.07
5/9	147.6	$641.93	45.5	$495.50	54.9	$377.36	24.9	$1,450.19
5/10	146.8	$638.59	45.5	$495.50	54.0	$371.06	24.7	$1,438.31
5/11	145.2	$631.40	45.5	$495.50	53.1	$364.86	24.5	$1,426.43
5/12	143.5	$624.21	45.5	$495.50	52.2	$358.77	24.3	$1,414.56
5/13	141.8	$617.03	45.5	$495.50	51.3	$352.78	24.1	$1,402.68
5/14	140.2	$609.84	45.5	$495.50	50.5	$346.89	23.9	$1,390.80
5/15	138.5	$602.65	45.5	$495.50	49.6	$341.09	23.7	$1,378.92
5/16	136.9	$595.46	45.5	$495.50	48.8	$335.40	23.5	$1,367.05
5/17	135.2	$588.27	45.5	$495.50	48.0	$329.80	23.3	$1,355.17
5/18	133.6	$581.08	45.5	$495.50	47.2	$324.29	23.1	$1,343.29
5/19	131.9	$573.90	45.5	$495.50	46.4	$318.87	22.9	$1,331.41
5/20	130.3	$566.71	45.5	$495.50	45.6	$313.55	22.7	$1,319.54
5/21	127.4	$554.17	45.2	$493.02	44.9	$308.31	22.5	$1,307.66
5/22	124.5	$541.63	45.0	$490.55	44.1	$303.16	22.3	$1,295.78
5/23	121.6	$529.09	44.8	$488.10	43.4	$298.10	22.1	$1,283.90
5/24	118.7	$516.56	44.5	$485.66	42.7	$293.12	21.9	$1,272.03
5/25	115.9	$504.02	44.3	$483.23	41.9	$288.23	21.7	$1,260.15

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Appendix Table F3. Continued								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
5/26	113.0	$491.48	44.1	$480.82	41.2	$283.41	21.4	$1,248.27
5/27	110.1	$478.94	43.9	$478.41	40.6	$278.68	21.2	$1,236.39
5/28	107.2	$466.41	43.7	$476.02	39.9	$274.03	21.0	$1,224.52
5/29	104.3	$453.87	43.4	$473.64	39.2	$269.45	20.8	$1,212.64
5/30	101.5	$441.33	43.2	$471.27	38.6	$264.95	20.6	$1,200.76
5/31	98.6	$428.79	43.0	$468.91	37.9	$260.53	20.4	$1,188.88
6/1	95.7	$416.25	42.8	$466.57	37.3	$256.18	20.2	$1,177.01
6/2			42.6	$464.24			20.0	$1,165.13
6/3			42.4	$461.92			19.8	$1,153.25
6/4			42.2	$459.61			19.6	$1,141.37
6/5			41.9	$457.31			19.4	$1,129.50
6/6			41.7	$455.02			19.2	$1,117.62
6/7			41.5	$452.75			19.0	$1,105.74
6/8			41.3	$450.48			18.8	$1,093.86
6/9			41.1	$448.23			18.6	$1,081.99
6/10			40.9	$445.99			18.4	$1,070.11
6/11			40.7	$443.76			18.2	$1,058.23
6/12								

Appendix Table F4. Target Crop Yields, Estimated Yield Declines, and Gross Revenue per Acre by Planting Date, Wilkin County, Minnesota

	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
4/15	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/16	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/17	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/18	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/19	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/20	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/21	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/22	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/23	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/24	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/25	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/26	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/27	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/28	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/29	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
4/30	167.1	$727.64			61.4	$422.22	27.6	$1,608.07
5/1	167.1	$727.64	44.8	$487.86	60.4	$415.16	27.6	$1,608.07
5/2	166.2	$723.83	44.8	$487.86	59.4	$408.23	27.4	$1,596.19
5/3	165.4	$720.19	44.8	$487.86	58.4	$401.41	27.2	$1,584.31
5/4	164.6	$716.55	44.8	$487.86	57.4	$394.71	27.0	$1,572.43
5/5	163.7	$712.92	44.8	$487.86	56.5	$388.12	26.8	$1,560.56
5/6	162.9	$709.28	44.8	$487.86	55.5	$381.64	26.6	$1,548.68
5/7	162.1	$705.64	44.8	$487.86	54.6	$375.26	26.4	$1,536.80
5/8	161.2	$702.00	44.8	$487.86	53.7	$369.00	26.2	$1,524.92
5/9	160.4	$698.37	44.8	$487.86	52.8	$362.83	26.0	$1,513.05
5/10	159.6	$694.73	44.8	$487.86	51.9	$356.78	25.8	$1,501.17
5/11	157.8	$686.91	44.8	$487.86	51.1	$350.82	25.6	$1,489.29
5/12	156.0	$679.09	44.8	$487.86	50.2	$344.96	25.4	$1,477.41
5/13	154.2	$671.27	44.8	$487.86	49.4	$339.20	25.2	$1,465.54
5/14	152.4	$663.45	44.8	$487.86	48.5	$333.53	25.0	$1,453.66
5/15	150.6	$655.63	44.8	$487.86	47.7	$327.96	24.8	$1,441.78
5/16	148.8	$647.81	44.8	$487.86	46.9	$322.49	24.6	$1,429.90
5/17	147.0	$639.99	44.8	$487.86	46.1	$317.10	24.4	$1,418.03
5/18	145.2	$632.17	44.8	$487.86	45.4	$311.80	24.2	$1,406.15
5/19	143.4	$624.35	44.8	$487.86	44.6	$306.60	24.0	$1,394.27
5/20	141.6	$616.53	44.8	$487.86	43.9	$301.48	23.8	$1,382.39
5/21	138.5	$602.89	44.5	$485.43	43.1	$296.44	23.5	$1,370.51
5/22	135.3	$589.25	44.3	$483.00	42.4	$291.49	23.3	$1,358.64
5/23	132.2	$575.61	44.1	$480.58	41.7	$286.62	23.1	$1,346.76
5/24	129.1	$561.97	43.9	$478.18	41.0	$281.84	22.9	$1,334.88
5/25	125.9	$548.33	43.6	$475.79	40.3	$277.13	22.7	$1,323.00

- continued -

Appendix Table F4. Continued								
	Corn		Soybeans		Wheat		Sugarbeets	
Date	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue	Yield	Gross Revenue
5/26	122.8	$534.69	43.4	$473.41	39.7	$272.50	22.5	$1,311.13
5/27	119.7	$521.05	43.2	$471.04	39.0	$267.95	22.3	$1,299.25
5/28	116.5	$507.41	43.0	$468.69	38.3	$263.48	22.1	$1,287.37
5/29	113.4	$493.77	42.8	$466.34	37.7	$259.08	21.9	$1,275.49
5/30	110.3	$480.13	42.6	$464.01	37.1	$254.75	21.7	$1,263.62
5/31	107.1	$466.49	42.3	$461.69	36.5	$250.50	21.5	$1,251.74
6/1	104.0	$452.85	42.1	$459.38	35.8	$246.31	21.3	$1,239.86
6/2			41.9	$457.09			21.1	$1,227.98
6/3			41.7	$454.80			20.9	$1,216.11
6/4			41.5	$452.53			20.7	$1,204.23
6/5			41.3	$450.27			20.5	$1,192.35
6/6			41.1	$448.01			20.3	$1,180.47
6/7			40.9	$445.77			20.1	$1,168.60
6/8			40.7	$443.55			19.9	$1,156.72
6/9			40.5	$441.33			19.7	$1,144.84
6/10			40.3	$439.12			19.5	$1,132.96
6/11			40.1	$436.93			19.3	$1,121.09
6/12								

Appendix G

Likelihood of Per-Acre Revenue Losses by Crop

Appendix Table G1. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Corn and Soybeans, 10-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			--------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Corn							
3	16.5	17.0	1 to 5	67.4%	32.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Na	na	6 to 10								
5	Na	na	11 to 15								
5	0	16.5	16 to 20	71.3%	26.1%	2.2%	0.4%	0.1%	0.0%	0.0%	0.0%
5	Na	na	Over 20								
				Soybeans[c]							
3	16.5	17.0	1 to 5	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Na	na	6 to 10								
5	Na	na	11 to 15								
5	0	16.5	16 to 20	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	Na	na	Over 20								

Na=not applicable. There were no storage areas in those categories.
WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

[c] Actual odds are not 100 percent that soybeans have no losses. The number of replications With a revenue loss for soybeans was too few to register in the rounding of the percentages.

Appendix Table G2. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Wheat and Sugarbeets, 10-year Flood Event											
	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			-------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Wheat							
3	16.5	17.0	1 to 5	67.2%	32.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Na	na	6 to 10								
5	Na	na	11 to 15								
5	0	16.5	16 to 20	70.9%	20.3%	6.7%	1.7%	0.4%	0.0%	0.0%	0.0%
5	Na	na	Over 20								
				Sugarbeets							
3	16.5	17.0	1 to 5	67.2%	32.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Na	na	6 to 10								
5	Na	na	11 to 15								
5	0	16.5	16 to 20	70.9%	12.5%	8.1%	4.4%	2.1%	1.2%	0.6%	0.2%
5	Na	na	Over 20								

Na=not applicable. There were no storage areas in those categories.
WO=Without Diversion, W=With Diversion
[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.
[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G3. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Corn and Soybeans, 25-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			--------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Corn							
3	19.8	22.8	1 to 5	36.6%	62.9%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.4	22.4	6 to 10	40.5%	48.9%	10.2%	0.3%	0.1%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.0	16 to 20	63.7%	32.3%	3.2%	0.6%	0.1%	0.0%	0.0%	0.0%
5	0	21.4	Over 20	47.7%	38.5%	10.7%	2.2%	0.6%	0.1%	0.1%	0.1%
				Soybeans							
3	19.8	22.8	1 to 5	97.3%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.4	22.4	6 to 10	98.2%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.0	16 to 20	99.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	21.4	Over 20	99.2%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Na=not applicable. There were no storage areas in those categories.

WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G4. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Wheat and Sugarbeets, 25-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			-------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Wheat							
3	19.8	22.8	1 to 5	36.6%	63.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.4	22.4	6 to 10	40.4%	30.3%	29.3%	0.0%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.0	16 to 20	63.5%	24.2%	8.7%	2.8%	0.7%	0.1%	0.0%	0.0%
5	0	21.4	Over 20	47.6%	24.7%	15.8%	7.9%	3.1%	0.9%	0.1%	0.0%
				Sugarbeets							
3	19.8	22.8	1 to 5	36.6%	28.6%	34.8%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.4	22.4	6 to 10	40.4%	18.0%	10.7%	15.1%	15.8%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.0	16 to 20	63.3%	14.2%	9.0%	5.3%	3.7%	2.0%	1.1%	1.4%
5	0	21.4	Over 20	47.6%	13.8%	9.8%	8.8%	6.6%	4.7%	3.6%	5.1%

Na=not applicable. There were no storage areas in those categories.
WO=Without Diversion, W=With Diversion
[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.
[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G5. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Corn and Soybeans, 50-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			-------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Corn							
3	20.3	23.3	1 to 5	32.8%	66.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%
3	17.2	23.2	6 to 10	44.1%	42.2%	13.2%	0.4%	0.2%	0.0%	0.0%	0.0%
5	0	14.0	11 to 15	81.7%	17.3%	0.9%	0.1%	0.0%	0.0%	0.0%	0.0%
5	0	17.8	16 to 20	59.6%	35.1%	4.2%	0.8%	0.1%	0.1%	0.0%	0.0%
5	0	22.2	Over 20	44.1%	39.0%	12.8%	2.9%	0.8%	0.2%	0.1%	0.1%
				Soybeans							
3	20.3	23.3	1 to 5	95.9%	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	17.2	23.2	6 to 10	98.8%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	14.0	11 to 15	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	17.8	16 to 20	99.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	22.2	Over 20	98.8%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Na=not applicable. There were no storage areas in those categories.

WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G6. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Wheat and Sugarbeets, 50-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			--------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Wheat							
3	20.3	23.3	1 to 5	32.8%	67.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	17.2	23.2	6 to 10	44.0%	22.5%	33.6%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	14.0	11 to 15	81.3%	14.7%	3.3%	0.7%	0.1%	0.0%	0.0%	0.0%
5	0	17.8	16 to 20	59.4%	26.8%	9.5%	3.3%	0.9%	0.1%	0.0%	0.0%
5	0	22.2	Over 20	44.0%	25.3%	16.3%	9.1%	3.9%	1.3%	0.2%	0.0%
				Sugarbeets							
3	20.3	23.3	1 to 5	32.8%	27.9%	39.3%	0.0%	0.0%	0.0%	0.0%	0.0%
3	17.2	23.2	6 to 10	44.0%	9.8%	10.0%	14.8%	21.4%	0.0%	0.0%	0.0%
5	0	14.0	11 to 15	81.3%	9.8%	4.7%	2.0%	1.1%	0.7%	0.3%	0.1%
5	0	17.8	16 to 20	59.4%	16.9%	8.7%	5.8%	4.1%	2.2%	1.3%	1.6%
5	0	22.2	Over 20	44.0%	14.9%	9.0%	8.9%	7.3%	5.3%	4.2%	6.4%

Na=not applicable. There were no storage areas in those categories.
WO=Without Diversion, W=With Diversion
[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.
[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G7. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Corn and Soybeans, 100-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			-------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Corn							
3	21.4	24.5	1 to 5	25.8%	73.2%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	18.4	25.1	6 to 10	29.1%	44.4%	25.0%	1.0%	0.4%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.7	16 to 20	59.6%	33.9%	5.3%	1.0%	0.2%	0.1%	0.0%	0.0%
5	0	22.6	Over 20	40.5%	42.0%	13.1%	3.2%	0.8%	0.3%	0.1%	0.1%
				Soybeans							
3	21.4	24.5	1 to 5	91.9%	8.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	18.4	25.1	6 to 10	94.3%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.7	16 to 20	99.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	22.6	Over 20	98.2%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Na=not applicable. There were no storage areas in those categories.

WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G8. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Wheat and Sugarbeets, 100-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			--------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Wheat							
3	21.4	24.5	1 to 5	25.8%	74.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	18.4	25.1	6 to 10	29.1%	24.2%	46.1%	0.5%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.7	16 to 20	59.4%	25.0%	10.5%	3.8%	1.1%	0.2%	0.0%	0.0%
5	0	22.6	Over 20	40.4%	27.8%	16.6%	9.4%	4.1%	1.4%	0.2%	0.0%
				Sugarbeets							
3	21.4	24.5	1 to 5	25.8%	40.5%	33.7%	0.0%	0.0%	0.0%	0.0%	0.0%
3	18.4	25.1	6 to 10	29.1%	13.7%	10.1%	12.4%	22.3%	12.5%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.7	16 to 20	59.4%	14.3%	9.4%	6.5%	4.3%	2.6%	1.4%	2.0%
5	0	22.6	Over 20	40.4%	17.9%	8.9%	9.1%	7.3%	5.4%	4.2%	6.7%

Na=not applicable. There were no storage areas in those categories.
WO=Without Diversion, W=With Diversion
[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.
[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G9. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Corn and Soybeans, 500-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	--------------------- days ---------------------			--------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Corn							
3	21.6	23.8	1 to 5	25.8%	73.8%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.5	24.8	6 to 10	40.5%	32.4%	23.4%	3.2%	0.4%	0.2%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.4	16 to 20	59.6%	35.1%	4.3%	0.8%	0.1%	0.1%	0.0%	0.0%
5	0	22.2	Over 20	40.5%	42.0%	13.1%	3.1%	0.9%	0.3%	0.1%	0.1%
				Soybeans							
3	21.6	23.8	1 to 5	91.9%	8.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.5	24.8	6 to 10	98.2%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.4	16 to 20	99.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0	22.2	Over 20	98.2%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Na=not applicable. There were no storage areas in those categories.

WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood With existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas Within the groups.

Appendix Table G10. Probability of Losses Resulting from Use of the Staging Area, Hydrology Groups Three and Five Delineated by Difference in Total Days between With and Without Diversion, for Wheat and Sugarbeets, 500-year Flood Event

	Time from Activation of Staging Area until the Effects of Flooding are over[a]			Per Acre Losses for Individual Crop							
Hydrology Group	WO	W	Difference in Total Days	No Loss	$0 to $25/acre[b] Loss	$26 to $50/acre[b] Loss	$51 to $75/acre[b] Loss	$76 to $100/acre[b] Loss	$101 to $125/acre[b] Loss	$126 to $150/acre[b] Loss	Over $150/acre[b] Loss
	-------------------- days --------------------			-------------------------------- Based on 10,000 replications from Monte Carlo Simulation -----------------------------------							
				Wheat							
3	21.6	23.8	1 to 5	25.8%	74.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.5	24.8	6 to 10	40.4%	15.9%	23.1%	20.6%	0.0%	0.0%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.4	16 to 20	59.4%	26.4%	9.5%	3.6%	1.0%	0.2%	0.0%	0.0%
5	0	22.2	Over 20	40.4%	27.4%	16.8%	9.5%	4.3%	1.4%	0.3%	0.0%
				Sugarbeets							
3	21.6	23.8	1 to 5	25.8%	36.4%	37.8%	0.0%	0.0%	0.0%	0.0%	0.0%
3	16.5	24.8	6 to 10	40.4%	6.2%	9.3%	9.0%	11.8%	23.3%	0.0%	0.0%
5	na	na	11 to 15								
5	0	18.4	16 to 20	59.4%	16.5%	8.9%	5.9%	4.1%	2.2%	1.4%	1.6%
5	0	22.2	Over 20	40.4%	17.9%	8.7%	9.2%	6.8%	5.9%	4.3%	6.9%

Na=not applicable. There were no storage areas in those categories.

WO=Without Diversion, W=With Diversion

[a] Total days are defined as the sum of 1) days from staging activation until land becomes inundated, 2) days of inundation, and 3) 10-day dry-down. Zero days mean the storage areas do not flood with existing conditions, but zero days do not necessarily mean conditions in the region are suitable for planting.

[b] The range of losses per acre represent an average of all storage areas within the groups.

Appendix H
Annual Crop Insurance Indemnities
Clay and Wilkin Counties, Minnesota
Cass and Richland Counties, North Dakota
1995 through 2012

Appendix Table H1. Revenues from Crop Enterprises, Cass County, North Dakota, 1995 through 2012				
Year	Cash Receipts from Crop Marketings	Government Payments[a]	Crop Insurance Indemnities[b]	Insurance Indemnitees as Percentage of Crop Revenues[c]
	-------------------------- 000s nominal $ --------------------------			
1995	183,496	11,751	5,175	2.58%
1996	197,879	12,935	1,123	0.53%
1997	186,837	13,179	5,990	2.91%
1998	155,291	27,709	6,306	3.33%
1999	167,507	52,856	14,946	6.35%
2000	149,137	60,672	7,542	3.47%
2001	155,423	53,708	8,982	4.12%
2002	201,324	13,109	4,454	2.03%
2003	203,324	23,461	8,039	3.42%
2004	192,571	18,360	24,321	10.34%
2005	179,333	34,220	8,435	3.80%
2006	204,251	18,044	3,961	1.75%
2007	245,523	15,207	33,094	11.26%
2008	360,081	22,342	24,432	6.01%
2009	333,386	12,896	20,681	5.64%
2010	372,099	23,007	14,846	3.62%
2011	366,784	18,419	97,558	20.21%
2012	448,334	12,964	9,844	2.09%

[a] Includes payments for conservation programs, federal disaster aid, and federal farm programs.
[b] Gross indemnities not adjusted for premiums paid.
[c] Crop revenues defined as the sum of cash receipts, government payments, and insurance indemnities.
Sources: U.S. Bureau of Economic Analysis (2014).

Appendix Table H2. Revenues from Crop Enterprises, Richland County, North Dakota, 1995 through 2012				
Year	Cash Receipts from Crops	Government Payments[a]	Crop Insurance Indemnities[b]	Insurance Indemnitees as Percentage of Crop Revenues[c]
	-------------------------- 000s nominal $ --------------------------			
1995	141,593	10,983	3,712	2.38%
1996	149,268	11,353	1,112	0.69%
1997	164,238	12,113	2,231	1.25%
1998	124,817	23,812	5,426	3.52%
1999	152,481	47,151	5,058	2.47%
2000	135,758	50,788	3,166	1.67%
2001	137,154	43,194	9,960	5.23%
2002	182,771	14,834	2,414	1.21%
2003	184,895	24,136	2,941	1.39%
2004	180,231	24,548	6,839	3.23%
2005	159,396	38,803	11,082	5.30%
2006	193,189	25,099	5,534	2.47%
2007	223,759	22,616	18,525	6.99%
2008	309,761	37,989	24,428	6.56%
2009	265,723	26,048	32,824	10.11%
2010	307,633	38,895	15,785	4.36%
2011	343,662	46,108	51,621	11.70%
2012	432,061	34,585	2,167	0.46%

[a] Includes payments for conservation programs, federal disaster aid, and federal farm programs.
[b] Gross indemnities not adjusted for premiums paid.
[c] Crop revenues defined as the sum of cash receipts, government payments, and insurance indemnities.
Sources: U.S. Bureau of Economic Analysis (2014).

Appendix Table H3. Revenues from Crop Enterprises, Clay County, Minnesota, 1995 through 2012				
Year	Cash Receipts from Crops	Government Payments[a]	Crop Insurance Indemnities[b]	Insurance Indemnitees as Percentage of Crop Revenues[c]
	---------------------------- 000s nominal $ ----------------------------			
1995	101,487	7,179	2,575	2.32%
1996	132,063	8,324	1,006	0.71%
1997	98,762	8,390	2,512	2.29%
1998	95,296	14,849	8,160	6.90%
1999	98,370	29,167	6,020	4.51%
2000	97,302	31,580	10,883	7.79%
2001	93,369	29,152	3,074	2.45%
2002	105,024	9,079	6,417	5.32%
2003	127,889	13,702	2,123	1.48%
2004	113,830	11,246	9,394	6.99%
2005	113,354	14,861	3,016	2.30%
2006	137,376	9,989	1,258	0.85%
2007	178,096	8,661	4,581	2.39%
2008	251,062	9,362	14,209	5.17%
2009	188,108	8,190	8,456	4.13%
2010	242,103	9,728	3,763	1.47%
2011	241,270	8,105	23,053	8.46%
2012	337,513	6,986	2,991	0.86%

[a] Includes payments for conservation programs, federal disaster aid, and federal farm programs.
[b] Gross indemnities not adjusted for premiums paid.
[c] Crop revenues defined as the sum of cash receipts, government payments, and insurance indemnities.
Sources: U.S. Bureau of Economic Analysis (2014).

Appendix Table H4. Revenues from Crop Enterprises, Wilkin County, Minnesota, 1995 through 2012

Year	Cash Receipts from Crops	Government Payments[a]	Crop Insurance Indemnities[b]	Insurance Indemnitees as Percentage of Crop Revenues[c]
	-------------------------- 000s nominal $ --------------------------			
1995	83,938	3,684	848	0.96%
1996	106,505	5,340	380	0.34%
1997	83,183	5,293	692	0.78%
1998	80,090	11,306	1,565	1.68%
1999	89,415	19,625	1,092	0.99%
2000	85,079	24,902	1,776	1.59%
2001	77,804	20,532	3,711	3.64%
2002	91,208	6,824	1,669	1.67%
2003	110,118	9,667	1,416	1.17%
2004	106,341	9,060	4,739	3.94%
2005	94,876	11,545	7,856	6.87%
2006	114,980	7,488	1,056	0.85%
2007	137,407	6,219	8,907	5.84%
2008	194,219	8,454	23,225	10.28%
2009	144,439	6,119	22,234	12.87%
2010	197,747	11,087	2,063	0.98%
2011	193,466	9,597	12,664	5.87%
2012	286,032	5,636	799	0.27%

[a] Includes payments for conservation programs, federal disaster aid, and federal farm programs.
[b] Gross indemnities not adjusted for premiums paid.
[c] Crop revenues defined as the sum of cash receipts, government payments, and insurance indemnities.
Sources: U.S. Bureau of Economic Analysis (2014).

Appendix I

Low, Average and High Per-Acre Revenue Losses by Crop due to Diversion, Hydrology Groups 3 and 5

Appendix Table I1. Per-Acre Revenue Losses, by Crop, due to Diversion (High and Low 5% of Observations and Average), Hydrology Group 3

	10-year	25-year	50-year	100-year	500-year	1997-Like
			-------------------------------- Corn --------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$0.75	-$5.46	-$6.16	-$9.16	-$5.54	-$12.61
Maximum (5%)	-$5.08	-$21.65	-$22.66	-$28.68	-$18.23	-$29.64
			--------------------------------- Wheat ---------------------------------			
Least (5%)	$0	$0	$0	$0	$0	-$0.01
Average	-$1.35	-$8.72	-$9.63	-$13.21	-$8.60	-$16.63
Maximum (5%)	-$6.66	-$23.47	-$24.13	-$30.06	-$20.06	-$29.34
			----------------------------- Sugarbeets -----------------------------			
Least (5%)	$0	$0	$0	$0	$0	-$0.02
Average	-$0.44	-$18.25	-$20.61	-$28.65	-$18.95	-$36.68
Maximum (5%)	-$2.61	-$51.81	-$53.84	-$68.22	-$44.73	-$64.73
			------------------------------- Soybeans -------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	$0	-$0.01	-$0.02	-$0.07	-$0.03	$0.56
Maximum (5%)	$0	-$0.30	-$0.45	-$1.33	-$0.63	-$7.04

Appendix Table I2. Per-Acre Revenue Losses, by Crop, due to Diversion (High and Low 5% of observations and Average), Hydrology Group 5

	10-year	25-year	50-year	100-year	500-year	1997-Like
			-------------------------------- Corn --------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$2.99	-$6.94	-$6.84	-$8.96	-$9.81	-$18.03
Maximum (5%)	-$29.98	-$49.60	-$48.73	-$57.66	-$61.10	-$79.77
			--------------------------------- Wheat ---------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$5.89	-$12.76	-$12.06	-$15.76	-$17.22	-$27.63
Maximum (5%)	-$51.07	-$76.23	-$73.12	-$84.10	-$88.28	-$102.45
			----------------------------- Sugarbeets -----------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	-$1.81	-$27.25	-$25.60	-$33.67	-$36.75	-$58.81
Maximum (5%)	-$16.77	-$163.08	-$156.50	-$179.97	-$188.08	-$219.31
			------------------------------- Soybeans -------------------------------			
Least (5%)	$0	$0	$0	$0	$0	$0
Average	$0	$0	$0	-$0.01	-$0.01	$0.09
Maximum (5%)	$0	-$0.05	-$0.07	-$0.14	-$0.16	-$1.73

These tables show the range of per-acre values observed given study data and averaging techniques of the statistical output from the model. Average values mask the variability observed in the analysis so a low and high value are reported as well. Observing at five percent eliminates potential low probability events whether the loss is low or high.