EXTREME CLIMATE EVENTS
PREPAREDNESS AND ADAPTATION
(EXTRA) PROJECT

Invitational Drought Tournament

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The Agri-Environment Services Branch (AESB) of Agriculture and Agri-Food Canada (AAFC) is committed to an integrated approach to sustainable agriculture, which recognizes that environmentally responsible and competitive agriculture are part of an interconnected system. The Branch brings ideas to the table and solutions to the sector, helping the sector make the best possible decisions for the environment, the economy and society. This includes supporting and developing new opportunities and enabling innovation, favouring a voluntary stewardship approach, and improving the sector’s public image.

Extreme climate events present both risks and opportunities for the agricultural sector (see Prairie precipitation figures below for a recent example of an extreme climate event). This sector is already sensitive to climate and weather, and further change or variability may be even more challenging if a more anticipatory, risk management approach is not adopted by decision making structures. It is important not only to understand the potential impacts of these extreme climate events on agriculture, but to also identify ways in which producers, institutions and other stakeholders can proactively prepare for, and perhaps even draw some benefits or opportunities from, these events. Since extreme climate events, such as drought, can present significant challenges, AAFC and its partners are working together through the EXtreme ClimaTe Events PrepaRedness and Adaptation (EXTRA) project to better prepare Canadian agriculture for future extreme climate events.

The project objectives are:

1. to engage various stakeholders in discussions and planning for extreme climate events preparedness and response specific to the agricultural sector;
2. to identify the strengths and gaps in institutional preparedness and response to future extreme climate events; and
3. to empower institutions to assess their institutional preparedness and response to future extreme climate events by providing them with a framework within which to conduct their assessment.

The purpose of the EXTRA project is to identify the strengths and gaps in institutional extreme climate events preparedness and response and build upon the assets and address the vulnerabilities in order to enhance future climate preparedness and adaptation. EXTRA, by design, promotes business risk management and advances planning under an uncertain future climate. By taking a proactive approach, it is assumed that certain climate impacts can be mitigated or adapted to before they become unmanageable. Furthermore, the high recovery costs from these climate events may be offset by planning response actions in advance. Preparing for extreme climate events before they happen can help to ensure that agri-business prospers even when disaster strikes.

The Invitational Drought Tournament (IDT) is a developmental framework, within EXTRA, designed to help institutions build their capacity around drought preparedness. The purpose of the IDT is to use a game format to help participants identify gaps and vulnerabilities surrounding drought preparedness. The IDT provides a forum for multi-disciplinary stakeholders to discuss climate preparedness and adaptation strategies in a workshop environment.

For the tournament, participants create their own multi-disciplinary teams, consisting of approximately five players. Teams then choose their initial conditions, or preparedness strategies. The teams are guided through a multi-year drought scenario of unknown length and severity, throughout which they will work collaboratively to discuss and select adaptation options that should help them better prepare for, adapt to, respond to, and recover from the drought's impacts. The chosen strategies should maximize economic benefits and reduce social and ecological stress.

**Important Note**

The tournament’s multi-year drought scenario does not represent a forecast of future drought. The scenario is based on a drought that was reconstructed from one that occurred in the early 1700s. Similar years were then chosen from the instrumental record to create the scenario participants will be guided through. Water demands in the scenario reflect current demands.

Teams will have the opportunity to choose their initial conditions prior to the tournament. The adaptation options have been predetermined, and the teams will be provided with a list of the options available to them. However, if a team develops an adaptation strategy they would like to use, it is up to the referees to decide on its cost and score. Adaptation options have been scored based on their ecological, social and economic, short-term and long-term risks by a team of experts. These experts represent various sectors and disciplines.

Teams will be given a budget and scenario each turn, and each turn represents one year. The scenario will include the landscape’s biophysical conditions as well as the drought’s impacts.
on the environment, the economy and society. After each turn, the teams will discuss the conditions and collaboratively decide on what adaptation options, if any, they will take given their budget and the following year’s probable weather conditions. The teams do not know how many turns they will be given throughout the duration of the tournament (i.e. how long the drought will last).

The goal of the game is to maximize your team’s economic potential, minimize social stress, and improve environmental conditions. After each turn, each team’s adaptation score will be calculated based on the scores associated with the options they have chosen, and the team with the lowest score (i.e. lowest cumulative ecological, social and economic, short-term and long-term impact) at the end of the tournament will win. The best score indicates the best institutional preparedness under an uncertain future climate.

**DEFINITIONS**

**Extreme climate event:** There are a number of ways extreme climate events can be defined. One example is by the rarity of their occurrence; extreme climate events are weather events that occur less than 5% of the time and are of higher intensity and/or duration than typically experienced. These events can include extreme daily temperatures, extreme daily rainfall amounts, large areas experiencing unusually warm monthly temperatures, or even storm events such as hurricanes. Extreme climate events can also be defined by the event’s impact on society. That impact may involve excessive loss of life, excessive economic or monetary losses, or both.

**Drought:** Drought can be defined in many ways. There is not one universally agreed upon drought definition, largely because the onset of drought is often difficult to determine, although most definitions allude to a precipitation deficiency. Often it is defined in terms of its primary impacts on agricultural productivity, soil moisture, reservoir levels and stream flow, for example, or by its economic impacts. Four distinct types of drought are described...
in the literature: meteorological, agricultural, hydrological and socio-economic. Meteorological drought refers to the departure from normal precipitation over a period of time. Agricultural drought refers to soil water availability to support crop and forage growth. Hydrological drought refers to the availability of surface and subsurface water supplies. Socio-economic drought refers to the supply of an economic good or service that is precipitation-dependent.¹

**Preparedness:** Preparedness, in this context, relates to the anticipatory planning for any event. In this context, we refer to preparedness in the context of extreme climate events.

**Million cubic meters (MCM):** Million cubic meters (MCM) is metric measure of volume that represents the volume of a cube with a length, width and depth of one million meters.

**Palmer Drought Severity Index (PDSI):** The Palmer Drought Severity Index (PDSI) is a moisture indicator, reflecting different degrees of dryness and wetness. For this exercise, PDSI is illustrated for July, and not other months, because this month is the most critical to livelihoods and ecosystems in the basin. For example, dry or wet conditions during the growing season (April to September) affect plant growth and can substantially lower quality and yields in both annual crops and perennial pasture.

**PAST EXTREME CLIMATE EVENTS**

Drought continues to be a high priority issue for Canada’s agriculture sector due to the associated economic, social and environmental impacts. Canada has spent almost $2 billion on emergency drought financial assistance to Canadian producers since 1980. This figure would likely be greater but AESB (formerly the Prairie Farm Rehabilitation Association – PFRA) and provincial agencies have been working to improve drought mitigation, adaptation, and response activities since the 1930s.

Although timely drought response measures will continue to be an important part of drought management, re-emphasis on preparedness through planning and adaptation will better prepare Canadian agriculture for inevitable future drought events.

Saskatchewan has experienced many droughts. In south-western Saskatchewan, a severe six year drought took place between 1917 and 1926 (Encyclopedia of Saskatchewan). This was soon followed by the Dustbowl of the 1930s. The Dustbowl was an ecological disaster that affected the Canadian prairies and the U.S. Great Plains. During this time it was extremely difficult for farmers to grow food, and many migrated to other farmlands or into the cities in search of work. However, with the Stock Market Crash in 1929, there were no jobs to be found during the 30s (The Canadian Encyclopedia). The drought dried up all the fertile land and so the soil eroded. The soil was literally blown away, leaving nothing on which to grow food (The Canadian Encyclopedia). The size and intensity of the 1961 drought exceeded even that of the Dirty Thirties, resulting in the driest parts of the province receiving only 45% of normal precipitation (Encyclopedia of Saskatchewan).

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4 Ibid.
5 Ibid.
The 1977 drought in western Canada cost over $100 million in additional electric power generation costs, $20 million in unanticipated fire-fighting charges, $10 million in emergency federal and provincial drought programs, plus losses in tourism and costs for additional water treatment. In comparison, the 1988 drought caused an estimated agricultural production loss of $1.8 billion. The recent drought of 2001 was determined to be the third most severe drought in the last 50 years and produced an estimated shortfall of $4 billion in grain revenues. Other socio-economic impacts of the 2001-2002 drought in Canada included employment losses totalling 41,000 and a fall in gross domestic product by $5.8 billion.

Drought has devastating impacts. It can affect seed germination and growth which influences yields; impede grass growth which reduces grazing potential; and reduce water availability and quality, leading to water scarcity. Temperature variability is also problematic. Excessive heat can damage crops and both native and tame grasses, increase evaporation rates which reduce water availability, cause hailstorms which damages crops and infrastructure, and cause crops to mature early which decreases quality.

In addition to drought, rural Saskatchewan populations are dealing with social stressors such as an aging population and youth out-migration. Economic pressures include international market fluctuations and low commodity prices. These factors, along with climate variability and change, stress rural communities and create vulnerabilities.

Adaptations: There are a wide range of adaptive strategies that help Canadians deal with climate, social, economic and political risk. Institutional programs are quite often used to cope with water stress. Producers invest in crop insurance, and they have adopted new agricultural practices such as zero or minimum till to mitigate water loss and soil erosion. Water management strategies include constructing dug outs and rural water pipelines, developing irrigation, and rationing water resources. Other adaptive strategies include diversifying income and operations by engaging in off-farm work and mixed farming, and using social networks to aid decision making. Adaptive strategies used for livestock management include culling herds, moving cattle out of a drought area, buying feed, trucking water in to drought areas, and buying land in non-drought stricken locations to use as a feed source.

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Droughts are natural phenomena that occur in virtually all regions of the world. Therefore it is important to develop drought preparedness plans in anticipation of these events in order to reduce their negative impacts on the environment, the economy and society. These plans should incorporate ways of dealing with drought in a timely, systematic manner to reduce negative drought impacts on the environment, the economy and society. The objective is to move from a reactive, crisis management approach to a more proactive risk management approach because as mentioned earlier, proactive risk management could reduce drought impacts and costs. Spiralling costs, substantial impacts on sectors beyond agriculture (e.g., increasing social and environmental losses), and water conflicts among users have motivated institutions to improve their drought preparedness and drought policy development. One major challenge for adopting drought preparedness strategies is that droughts have a relatively slow onset, they are difficult to forecast, and there is no universal definition of drought (i.e. it means different things to different people and different sectors). Drought is an extremely complex phenomenon, and there is no universal solution to preparing for droughts.

Recent Innovation: Groasis Waterboxx

The Groasis waterboxx was developed in The Netherlands. It produces and captures water from the air. With the waterboxx, one, two, or three trees, bushes or vegetables can be planted in the centre of the boxx virtually anywhere. The waterboxx offers the possibility to plant multiple trees, bushes or vegetables at a time, allowing the least successful individual(s) to be cut after the first year, leaving the more successful individual(s) in the boxx to continue growth. By planting more than one individual the grower enhances the chances of ending up with at least one survivor plant. For more information on the waterboxx and how it works please visit: http://www.groasis.com/page/uk/faq.php

Photo credit: Groasis.com
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Invitational Drought Tournament

Tournament Rules

1. The goal of the tournament is for teams to choose adaptation options that reduce ecological, social, and economic drought risk in both the short-term (1 year) and long-term (15 years). Teams must also stay within their budget. The team that reduces its risk the most will win the tournament.

2. Respect other people’s opinions and perspectives.

3. Adaptation options address EITHER the hydrologic (streamflow) drought OR the agricultural drought (Palmer Drought Severity Index – soil moisture, precipitation, temperature) components of the scenario. Keep this in mind when purchasing adaptation options, as your task is to reduce both hydrologic and agricultural drought risk. Hydrologic and agricultural adaptation options each have a score. Adaptation option scores will be added together to arrive at a final risk reduction score.

4. Assign a team member to keep track of the budget.

5. Assign a team member to keep track of the water balance.

6. Assign a team member to record the adaptation options your team chooses to purchase and explain why these options were chosen.

Oxbow Basin Characteristics

This section provides a detailed description of the Oxbow Basin, which will be the “playing” area for the IDT scenario. This basin is fictitious and has been created for the purposes of this tournament. Please familiarize yourself with the basin and its characteristics prior to the tournament to ensure maximum preparedness and competition.

The Oxbow Basin, located in Canada, spans an area of 175,000 km², with a population of approximately 3,000,000 people. There are four cities distributed throughout the basin, all of which rely on surface water from rivers as their primary source of drinking water (Figure 1). Many small communities are also scattered across the basin; however, their main source of drinking water is groundwater. Municipal needs account for 14% of water demand in the basin, and agriculture, a very important sector in the basin, accounts for 75% of water
demand. The majority of agricultural demand in the basin stems from irrigation. Industry, including power generation and oil and gas, demands 4% of the water in the basin, while the remaining 7% is used for ‘other’ purposes such as in-stream flow needs, wildlife habitat, etc (refer to Figure 2).

![Figure 1: Oxbow basin, Canada](image)

Although a variety of land uses are present, agriculture uses over 90% of the basin’s landbase. Approximately 50% of the agricultural land is used for cropping, 45% for pasture, and the remainder is either summerfallow (i.e. tilled bare soil not under cultivation) or under other uses. Irrigation is applied to 10% of the agricultural land (4,300,000 acres) and is the single largest consumer of water in the basin (Figure 2). Irrigation farming takes places primarily in the western portion of the basin, while dryland farming and ranching are dispersed throughout. There are over 15,000 farmers engaged in a wide array of agricultural production types, including dairy, beef, hog, poultry, grain, oilseed, fruit and vegetables. Average farm size in the basin is 2,600 acres, and there are approximately 1,000,000 acres of marginal land being cultivated.

![Figure 2: Water demands in the Oxbow basin by sector](image)

The climate in the basin is characterized as semi-arid. Figure 3 provides an illustration of the climate averages for the basin’s four cities: Blowy Meadow, Concepcion, Smallville and Burnt Creek. The 30-year climate average demonstrates the long-term weather patterns in an area. These same data are summarized in Table 2. The highest amount of precipitation typically falls in the summer months, and the lowest amount in winter; precipitation ranges from 15 to 25 mm in January to 75 to 80 mm in July. Since the basin is located in Canada
(Northern Hemisphere), temperatures are lower in winter and higher in summer; temperatures range from -18 to -5 degrees Celsius in January to 15 to 20 degrees Celsius in July. Concepcion is the wettest city in the basin (466 mm/year), while Burnt Creek is the driest city (423 mm/year). Burnt Creek is the coldest city in winter (average of -18 °C) and the warmest city in summer (average of 19 °C). Blowy Meadow is the warmest city in the winter (average of -8 °C), and Concepcion is the coolest city in summer (average of 16 °C).

The river systems in the basin are fed primarily by snowmelt from the High Mountains, located to the west of the basin. There are reservoirs scattered throughout the basin, which store water for release during peak demand (e.g., irrigation season). In most years there is 1314 million cubic meters (MCM) of water in storage. Table 1 provides a summary of average naturalized stream flow (i.e. without consumptive uses taken into account) and demand. The water balance (natural stream flow minus demand, or A-B in Table 1) is positive, which means that, on average, the basin has a surplus of water.

Table 1: Average stream flow, water use and storage in the basin (Million Cubic Meters – MCM)

<table>
<thead>
<tr>
<th>A) Water available to satisfy demands</th>
<th>4266</th>
</tr>
</thead>
<tbody>
<tr>
<td>B) Demands</td>
<td></td>
</tr>
<tr>
<td>Municipal (e.g., drinking water, household use) (14%)</td>
<td>460</td>
</tr>
<tr>
<td>Agriculture (e.g., irrigation, livestock watering) (75%)</td>
<td>2463</td>
</tr>
<tr>
<td>Industry (e.g., energy, mining, tourism, recreation) (4%)</td>
<td>131</td>
</tr>
<tr>
<td>Other (e.g., in-stream flow needs, habitat) (7%)</td>
<td>230</td>
</tr>
<tr>
<td>Total</td>
<td>3284</td>
</tr>
<tr>
<td>Difference (A-B)</td>
<td>+982</td>
</tr>
<tr>
<td>Storage</td>
<td>1314</td>
</tr>
</tbody>
</table>

Grains are widely grown in the basin. Average grain yields range from moderate to high (Figure 4). Grain crops in the northern portion of the basin tend to yield higher on average than those in the southern portion. Many producers also rely on farm water supplies for their operations’ success. Generally producers do not experience water shortages (Figure 5). However, since it is a semi-arid basin, producers have made significant efforts to secure their water supply by building extra storage, for example, which fills in years of surplus for use in years of shortage.

Soil erosion, for the most part, is not a major issue in the basin (Figure 6). Years of excess moisture or drought tend to increase soil erosion risk in areas classified as moderate to high risk. In excess moisture years, water can impede seeding and/or harvest, erode the soil, and create ruts on roads and other issues in fields. Excess moisture is also problematic for communities as there is an increased risk of flooding and water contamination. In drought years, wind can erode the soil and cause the loss or transport of nutrients as well as cause dust storms, which visibility and human health.

Since the majority of the basin is under agriculture, much of the land is used by wildlife as habitat (Figure 7). The wildlife habitat capacity for the majority of the basin is considered to be moderate.
Figure 3: Climate graphs (agricultural year) for Blowy Meadow, Concepcion, Smallville and Burnt Creek
Table 2: Average monthly temperature (°C) and precipitation (mm) for the agricultural year in Blowy Meadow, Concepcion, Smallville and Burnt Creek

<table>
<thead>
<tr>
<th></th>
<th>Concepcion</th>
<th>Blowy Meadow</th>
<th>Smallville</th>
<th>Burnt Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>10.6</td>
<td>52.6</td>
<td>12.4</td>
<td>45.5</td>
</tr>
<tr>
<td>October</td>
<td>5.7</td>
<td>19.4</td>
<td>7.6</td>
<td>17.6</td>
</tr>
<tr>
<td>November</td>
<td>-3.0</td>
<td>17.7</td>
<td>-0.9</td>
<td>20.3</td>
</tr>
<tr>
<td>December</td>
<td>-8.4</td>
<td>19.9</td>
<td>-6.1</td>
<td>27.0</td>
</tr>
<tr>
<td>January</td>
<td>-9.7</td>
<td>19.1</td>
<td>-8.1</td>
<td>29.1</td>
</tr>
<tr>
<td>February</td>
<td>-6.4</td>
<td>16.1</td>
<td>-5.0</td>
<td>17.6</td>
</tr>
<tr>
<td>March</td>
<td>-2.6</td>
<td>21.3</td>
<td>-0.6</td>
<td>30.1</td>
</tr>
<tr>
<td>April</td>
<td>4.1</td>
<td>31.4</td>
<td>5.9</td>
<td>38.8</td>
</tr>
<tr>
<td>May</td>
<td>9.7</td>
<td>58.5</td>
<td>11.5</td>
<td>51.5</td>
</tr>
<tr>
<td>June</td>
<td>14.0</td>
<td>82.5</td>
<td>15.8</td>
<td>68.7</td>
</tr>
<tr>
<td>July</td>
<td>16.4</td>
<td>75.1</td>
<td>18.2</td>
<td>42.7</td>
</tr>
<tr>
<td>August</td>
<td>15.7</td>
<td>52.7</td>
<td>17.7</td>
<td>47.9</td>
</tr>
<tr>
<td>Annual</td>
<td>466.1</td>
<td>436.8</td>
<td>434</td>
<td>422.5</td>
</tr>
</tbody>
</table>

Figure 4: Average grain yields in the Oxbow basin
Figure 5: Average water supply levels in the Oxbow basin

Figure 6: Risk of soil erosion in the Oxbow basin

Figure 7: Wildlife habitat capacity for terrestrial vertebrates using agricultural land in the Oxbow basin for breeding and feeding
Tournament Roles

Each team member is representing a certain stakeholder perspective in the tournament. Team members are asked to represent their perspective to the best of their ability in order to facilitate meaningful discussion. Each team is comprised of participants with water, agriculture, environment, industry and policy perspectives.

The following is a list of roles people will play in the tournament:

- **Organizers**
  - Describe the drought scenario
  - Observe the process overall
  - Make course correction as necessary
  - Score teams after each round

- **Team Captains**
  - Facilitate decision making on the team
  - Guide and lead the process for the team
  - Team spokesperson that interacts with Organizers

- **Players**
  - Play the role assigned
  - Engage and participate

- **Referees**
  - “Content” experts able to “make the call” if they need to
  - Provide expert advice to teams
  - Develop report with observations focused on the “content” of the activity

- **Facilitator**
  - Facilitate the process overall
  - Develop report with observations focused on the “process” – the conduct of the activity

- **Observers or “Fans”**
  - Primarily from academia
  - Observe the exercise, provide feedback, and possibly apply what they learn to their own research

Future Probabilities

The following section summarizes the probabilities of entering different degrees of dryness or wetness consecutive years based upon the previous year’s condition. Table 3 provides a detailed description of the percentile categories used for this exercise to reflect different degrees of dryness and wetness. These five percentile categories were developed out of
stream flow reconstructions from tree rings for 1402 to 2003, which is correlated with the Palmer Drought Severity Index (PDSI) – a measure of dryness and wetness based on temperature and precipitation, and form the basis for the transition matrix in Table 4.

Table 3: Percentile categories used to develop the transition matrix and the biophysical conditions associated with each category.

<table>
<thead>
<tr>
<th>Percentile categories</th>
<th>Water-related conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low (0-20th)</td>
<td>Stream flow is less than or equal to the lowest 20% of the values in the historical record. Reflects extremely dry conditions.</td>
</tr>
<tr>
<td>Low (20th-40th)</td>
<td>Stream flow is greater than the lowest 20% and less than or equal to the lowest 40% of the values in the historical record. Reflects dry conditions.</td>
</tr>
<tr>
<td>Average (40th-60th)</td>
<td>Stream flow is greater than the lowest 40% and less than or equal to the lowest 60% of the values in the historical record. Reflects average conditions.</td>
</tr>
<tr>
<td>High (60th-80th)</td>
<td>Stream flow is greater than the lowest 60% and less than or equal to the lowest 80% of the values in the historical record. Reflects wet conditions.</td>
</tr>
<tr>
<td>Very high (80th-100th)</td>
<td>Stream flow is greater than the lowest 80% or less than or equal to the highest values in the historical record. Reflects extremely wet conditions.</td>
</tr>
</tbody>
</table>

Table 4 shows the probabilities of scenario Year 2 falling in categories very low through very high. These probabilities are based on Year 1 conditions being very low. The matrix, and the probabilities, would be different if Year 1 was a different category. The entries in the first row of the matrix (P) represent the probabilities of next falling in categories 1 through 5, given that Year 1 was ‘very low’. That is, \( p_{11} = 0.3636 \) indicates that if Year 1 was ‘very low’ there is a 36% chance Year 2 will be ‘very low’, \( p_{15} = 0.0579 \) indicates that if Year 1 was very low there is a 5.79% chance Year 2 will be ‘very high’. This information provides insights into next year’s conditions based on probabilities from the reconstructed and instrumental climate record, which may be useful to participants when choosing their adaptation options.

Table 4: Probabilities of Year 2 falling in categories 1 through 5 based on Year 1 being a category 1

<table>
<thead>
<tr>
<th>Year 2</th>
<th>1: Very low</th>
<th>2: Low</th>
<th>3: Average</th>
<th>4: High</th>
<th>5: Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( P_{11} ): 0.36364</td>
<td>( P_{12} ): 0.25620</td>
<td>( P_{13} ): 0.20661</td>
<td>( P_{14} ): 0.11570</td>
<td>( P_{15} ): 0.05785</td>
</tr>
</tbody>
</table>
Each team will be given a budget to implement adaptation options throughout the scenario, and they are able to spend it as they wish; they can opt to do nothing or they can choose as many adaptation options as they want, so long as they have the budget. A list of adaptation options available for implementation will be provided to the teams. Each adaptation option addresses either the hydrologic (streamflow) OR agricultural (PDSI - soil moisture, precipitation, temperature) components of the scenario. Options were predetermined (this list is not exhaustive), as have their scores, by a team of experts through a risk assessment process described in the Adaptation Scores section below. Future budgets are uncertain and therefore teams do not know whether or not their budget will carry forward to subsequent years. Teams will be required to keep track of their budget and expenditures, their water balance, and the adaptation options they select.

Teams also have the opportunity to define their initial conditions prior to the tournament. Teams will be given a pre-tournament adaptation budget (see box below) that can be used to ‘purchase’ adaptation options from the list in Table 5. Team Captains must provide their team’s adaptation selections, if any, to the tournament organizers by February 8th, 2011.

Pre-tournament adaptation budget: $950,000,000

<table>
<thead>
<tr>
<th>Adaptation option</th>
<th>Adaptation type</th>
<th>Details</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enhance irrigation water delivery system and application efficiency by 25%</td>
<td>Long-term strategy that takes 5 years to implement. This strategy will be completed prior to the scenario</td>
<td>300,000 acres have been converted to high efficiency irrigation and 1000 kms of canal have been lined with concrete to reduce seepage</td>
<td>$193,000,000</td>
</tr>
</tbody>
</table>
| **Divert water from another basin to the Oxbow** | **Long-term Infrastructure strategy that takes 10 years to implement. This strategy will be completed prior to the scenario** | **Inter-basin water transfer of 250 MCM every year*** **teams must add 250 MCM every year to their water budget if they purchase this adaptation option*** | **$840,100,000** (includes construction of diversion, reservoir and maintenance)**

This diversion involves the construction of a pipeline and reservoir.

| **Build a dam and reservoir** | **Long-term strategy that takes 10 years to implement. This strategy will be completed prior to the scenario** | **Water storage capacity is increased by 500 MCM in the Oxbow basin by constructing a dam and reservoir*** **Teams must add 500 MCM to their 2013 water budget if they purchase this adaptation option*** | **$477,000,000** (includes maintenance)**

| **Land Management** | **Promote green cover** | **Long-term operation management strategy aimed at changing land use in the basin** | **150,000 acres of marginal annual cropped land at risk of soil degradation has been converted to perennial cover** | **$12,750,000**

| **Promote diversification of pasture species composition** | **Long-term strategy to diversify species composition of pastures** | **A program has been completed to promote seeding of a variety of species in pastures (i.e. early and late season and cool and warm shrubs and plants)** | **$1,000,000**

| **Technology** | **Expand irrigation** | **Long-term strategy to convert dryland to irrigated farming** | **500,000 acres of high efficiency irrigation have been added to the basin** | **$149,000,000**


| Invest in water-related research and development | Long-term strategy to investigate alternative drought adaptation strategies | New and innovative ways to adapt to dry conditions have been developed | $102,000,000 |
| Invest in agriculture-related research and development | Long-term strategy to investigate alternative drought adaptation strategies | New and innovative ways to adapt to dry conditions have been developed for agriculture | $102,000,000 |
| Invest in grey water treatment | Long-term water conservation strategy to recycle and reuse water | 50,000 homes in the basin have been equipped with grey water treatment technology for toilet and laundry | $51,000,000 |

**ADAPTATION SCORES**

The adaptation options available for implementation were scored in advance by a team of experts using a modified risk assessment framework. There are four steps in the modified risk assessment process:

1. **Issue definition**: provide a problem statement
2. **Screen and characterize extent and severity**: determine whether or not an issue is significant and collect the information necessary to score and rank the issue
   - Ecological criteria
   - Social criteria
   - Economic criteria
   - Short-term needs (1 year)
   - Long-term needs (15 years)
3. **Risk scoring (scenario and adaptation options)**
4. **Totalling scores**

The four steps listed above were completed by the project team in order to determine the scores for the adaptation options. The first three steps were undertaken in collaboration with partners and stakeholders. A multi-disciplinary expert committee was assembled to ensure representation from a variety of perspectives.
The first step in the risk assessment involves defining the issue and clearly defining the problem. Eleven experts from various disciplines and governments formed the expert committee and gathered at a meeting to achieve step one. The problem defined by the expert committee at this meeting was: there is a lack of understanding surrounding the impacts of drought risks in the Oxbow Basin and the changes in risk associated with various adaptation strategies.

The second step consists of screening and characterizing extent and severity endpoints. Since the goal of the game is for teams to maximize the basin’s economic potential, minimize social stress and improve environmental conditions (based on the three pillars of sustainability), the expert committee began step two by characterizing the drought extent (Table 6) and drought severity criteria for the ecological and socio-economic scoring categories (Table 7). The expert committee decided what would be considered a minor to critical ecological and socio-economic drought extent and a minor to severe ecological and socio-economic drought severity (see “Extent characteristics” and “Description and examples” columns in Tables 6 and 7, respectively). The expert committee determined that a critical extent with a score of eight, for example, would manifest in impacts on a watershed-wide basis. The committee also determined that an ecological severity of moderate with a score of four, for example, would be described as changes in size of nutrient pools, cycling and decomposition processes, energy fluxes and/or changes in in-stream flow during critical stages of some aquatic life. These tables were used as the framework to evaluate and score the drought scenario.

**Table 6: Scores characterization of extent**

<table>
<thead>
<tr>
<th>Scoring category</th>
<th>Extent score</th>
<th>Extent characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>8</td>
<td>Impacts on a watershed-wide basis</td>
</tr>
<tr>
<td>Serious</td>
<td>4</td>
<td>Greater than 50% of the watershed is impacted.</td>
</tr>
<tr>
<td>Adverse</td>
<td>2</td>
<td>Less than 50% in a watershed; effect is seen but perhaps in only one sub-basin or regional business (e.g. community)</td>
</tr>
<tr>
<td>Minor</td>
<td>1</td>
<td>Limited extent impacting on a site-specific area</td>
</tr>
</tbody>
</table>
## Table 7: Ecological and socio-economic severity criteria and descriptions

### Characterization of Ecological Severity and Risks (step 2)

<table>
<thead>
<tr>
<th>Scoring category</th>
<th>Severity score</th>
<th>Description and examples</th>
</tr>
</thead>
</table>
| **Severe**       | 9              | Ecosystem structure and function are fundamentally changed in a non-reversible manner:  
                    • Significant permanent habitat loss within a watershed |
| **Serious**      | 7 – 8          | Ecosystem structure and function are damaged; species and populations decline and communities change; habitats and abiotic resources are lost; less robust food chain:  
                    • Decline in suitable habitat for species persistence (e.g. decreased carrying capacity) |
| **Moderate**     | 4 – 6          | Ecosystem structure or functions affected; infrequent or intermittent effects; individuals may die but populations are not at risk; habitat is intact; impairment of primary processes; loss of resilience:  
                    • Changes in habitat during critical stages of some terrestrial life |
| **Minor**        | 1 – 3          | Ecosystem structure and functions are exposed to stress but system integrity is intact, transitory effects on habits, species or individuals:  
                    • Small changes in habitat but does not unduly affect species persistence |

### Characterization of Socio-Economic Severity and Risks (step 2)

<table>
<thead>
<tr>
<th>Scoring category</th>
<th>Severity score</th>
<th>Description and examples</th>
</tr>
</thead>
</table>
| **Severe**       | 9              | Permanent decline or loss of the economic value of activities without capacity of substitution or adaptation. Community decline and loss of population, community way of life is lost  
                    • Water resource use no longer sustainable (>50% of water demands not met), permanent job loss  
                    • Communities may be abandoned; massive out-migration  
                    • Widespread exit from agricultural sector, extensive bankruptcies, major impacts on financial institutions, inability to pay inputs |
| **Serious**      | 7 – 8          | Reversible reduction in the value of economic activities where recovery is possible or substitutes are available but at a major additional cost. Loss of community infrastructure and public services: |
To accomplish the third step, each year of the drought scenario (without adaptation) was assessed relative to the extent and severity framework (Tables 6 and 7) by the expert committee. Therefore, each year of the scenario has an ecological extent, ecological severity, socio-economic extent and socio-economic severity score associated with it. These scores were tallied to calculate the total drought risk score for each year, which provided the baseline for scoring the adaptation options. The scores for the adaptation options are based on their effectiveness in reducing ecological, social and economic drought risk and meeting short-term (1 year) and long-term (15 years) needs on a scale of 0 to 1; 0 means a 0% percent reduction in risk or that the option does not address short- or long-term needs; 1 means a 100% reduction in risk or that the option addresses all short- or long-term needs. One key assumption in the scoring process is that drought risk can be reduced by 100% if all pre-drought and yearly adaptation options are employed in each year of the scenario.

Table 8: Adaptation option risk assessment scoring process

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Ecological risk</th>
<th>Social risk</th>
<th>Economic risk</th>
<th>Short-term needs</th>
<th>Long-term needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing a dugout</td>
<td>0</td>
<td>20%</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

An example of the adaptation option scoring process can be found in Table 8. Constructing a dugout, for example, would likely not reduce ecological drought risk. It would reduce social
drought risk by 20% because it helps secure the on-farm water supply and causes farmers less stress, although it also means less water is available for other uses. It would reduce economic drought risk by 10% because the more secure water supply would help get farmers through a drought and reduce the amount of hauling. In the short-term, so long as the dugout has sufficient water, it would meet 20% of farmers’ needs, as it would allow them to continue watering their cattle and reduce the need to haul. In the long term, the dugout would meet 20% of farmers’ needs because it would serve as an additional water supply and help farmers get through times of shortage.