Waterfowl Impacts of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project – An effects analysis tool

October 20, 2017

Prepared for:
California Department of Water Resources

Prepared by:
Ducks Unlimited,
Western Regional Office,
3074 Gold Canal Drive, Rancho Cordova, CA 95670

Contents

List of Figures

List of Tables

.

1 Executive Summary

The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project proposes to increase fish habitat functions and values within the Yolo Bypass through the activation of floodplain processes by increasing the frequency, duration, and amount of flooding over the Fremont Weir between November and April. To evaluate various management alternatives under which the Project might operate and understand how the effects of those alternatives on waterfowl may either be minimized or off-set, this analysis designed a tool to model the effects on waterfowl and their habitat resulting from a change in Yolo Bypass flood management. Waterfowl habitat for the purposes of this analysis is defined as managed seasonal wetlands and winter flooded rice fields.

Potential flood flows through the future operation of gated notch variations in the Weir were analyzed. We evaluated the effects of five management alternatives (Existing Conditions and operational Alternatives 1, 4, 5 & 6) in three water years representing an exceedingly wet year (1999), a dry year (2002) and a wetter than normal year (2005). California Department of Water Resources provided the hydrologic modeling data via TUFLOW©. The hydrologic modeling data for the three years was used in combination with the landcover data to produce the amount of accessible and non-accessible acres of habitat available for waterfowl forage. These results were utilized to run the TRUEMET model to determine the potential impact to waterfowl from these Alternatives.

Comparisons were made to the Central Valley Joint Venture's (CVJV) current assumptions about food energy resources in the Yolo Basin planning area and between the Existing Conditions alternative and the four operational alternatives. The findings indicate that in the exceedingly wet year (1999) there were impacts to food forage availability in late November to December. However, there was very little change to the point when supply of food falls below food demand. This trend is repeated fairly consistently for each of the water years modeled and each of the alternatives. In each case, Alternatives 1 and 6 have the most impact on food supply mid-winter but none of the alternatives significantly alter the point at which demand exceeds supply in late-winter/early spring (less than 2-3 days).

The potential future changes as a result of the alternatives may be a reduction in hunter opportunity. Hunting opportunity and the long-term incentive to invest in the management of seasonal wetlands significantly drive the supply availability. Reductions in supply as a result of lost hunter opportunity would result in less food available and might ultimately cause demand to exceed supply earlier than under current and existing conditions.

2 Background

The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) has been developed to improve fish passage and increase floodplain fisheries rearing habitat in Yolo Bypass and the lower Sacramento River basin. The United States Department of the Interior, Bureau of Reclamation (Reclamation), as the Federal lead agency under the National Environmental Policy Act (NEPA), and the California Department of Water Resources (DWR), as the State of California (State) lead agency under the California Environmental Quality Act (CEQA), have prepared a joint Draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR) to assess impacts of the Project.

The Project actions would implement Reasonable and Prudent Alternative (RPA) action I.6.1 and, in part, RPA action I.7, as described in the 2009 National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project* (NMFS BO) and the 2012 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan (Reclamation and DWR 2012).

The 2012 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan (Implementation Plan) was prepared jointly by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) to address two specific RPA Actions set forth in the NMFS Operation BO:

RPA Action I.6.1: Restoration of Floodplain Rearing Habitat, through the increase of seasonal inundation within the lower Sacramento River basin; and

RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon, through the modification of Fremont Weir and other structures of the Yolo Bypass.

The Implementation Plan considers alternatives to increase juvenile fish rearing in the Yolo Bypass when the floodplain is inundated and improve adult fish passage at the Fremont Weir. While these actions are expected to improve fish habitat functions, there are concerns that there is the potential for the actions to have negative impacts on existing waterfowl habitat in the Yolo Bypass because existing managed wetlands and rice fields could be flooded at depths too great to allow for waterfowl foraging. Dabbling waterfowl prefer to forage in very shallowly flooded seasonal wetlands, but can feed in relatively deeper areas by upending as shown in Figure 1. Due to their physiology, they are limited to foraging in water depths of less than 18 inches (Nelson, 2012; Fredrickson, 1982) with preferred foraging depths less than 10 inches.

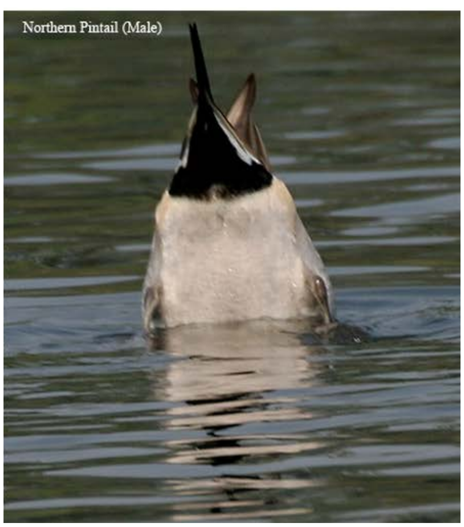


Figure 1. Upending dabbling ducks have a limit to the depth of water that allows foraging (Garg, 2007)

Five alternatives were evaluated under three historic water year conditions that represent a wet water year (1999) a dry water year (2002), and an above normal (wetter than normal) water year (2005). The three water years were chosen to represent years where there were flooding events that occurred in December, January, and February (the period of heaviest waterfowl usage in the Bypass) and where there were noticeable differences in the extent of flooding exhibited by the various alternatives in comparison to existing conditions in that year.

For each water year five alternatives were evaluated and included: No Action (Existing conditions), Alternative 1, Alternative 4, Alternative 5 and Alternative 6.

Alternative 1: East Side Gated Notch

Alternative 1, East Side Gated Notch, would allow increased flow from the Sacramento River to enter the Yolo Bypass through a gated notch on the east side of Fremont Weir. The invert of the new notch would be at an elevation of 14 feet, which is approximately 18 feet below the existing Fremont Weir crest. Water would be able to flow through the notch during periods when the river levels are not high enough to go over the crest of Fremont Weir (at an elevation of 32 feet).

Alternative 4: West Side Gated Notch – Managed Flow

Alternative 4, West Side Gated Notch – Managed Flow, would have a smaller amount of flow entering the Yolo Bypass through the gated notch in Fremont Weir than the other alternatives, but it would incorporate water control structures to maintain inundation in defined areas for longer periods of time within the northern Yolo Bypass. Alternative 4 would include the same gated notch and associated facilities as described for Alternative 3 (see Draft EIS/EIR document for Alternative 3 description). However, it would be operated to limit the maximum inflow from exceeding 3,000 cfs.

Alternative 5: Central Multiple Gated Notches

Through the strategy of using multiple gates and intake channels, Alternative 5, Central Multiple Gated Notches, has the goal of increasing the number of outmigrating juvenile fish that enter the Yolo Bypass. Trapezoidal channels create some limitations for fish passage because they have smaller flows at lower river elevations (because the channel is smaller at this elevation) when winter-run Chinook salmon are outmigrating. Alternative 5 includes multiple gates so that the deeper gate could allow more flow to enter the bypass when the river is at lower elevations. But flows would move to other gates when the river is higher to control inflows while maintaining fish passage conditions.

Alternative 6: West Side Large Gated Notch

Alternative 6, Large Gated Notch, is a large notch in the western location that would allow flows up to 12,000 cfs to enter the Yolo Bypass. It was designed with the goal of entraining more fish with the strategy of allowing more flow into the bypass when the Sacramento River is at lower elevations. Typically, winter-run Chinook salmon move downstream during the first high flow event of the season. This flow event is sometimes not high enough to result in what would be substantial flows into the bypass under Alternatives 1 through 5. The gated notch could allow more flow to enter during winter-run Chinook salmon outmigration, potentially maximizing fish entrainment.

Four main drivers or effects on waterfowl from increased flooding in the Yolo Bypass include: 1) changes to recreational use; 2) loss of farming and hunting income; 3) reductions in waterfowl foraging habitat; and 4) the loss of wetland seed production due to later spring drawdown of the inundated floodplain. The work conducted under this Task Order provides a method to evaluate the effect on waterfowl foraging habitat and therefore the capacity of the Yolo Bypass to support its proportion of waterfowl population goals as defined in the Central Valley Joint Venture's Implementation Plan (as derived from the North American Waterfowl Management Plan).

3 Overview of the Waterfowl Effects Analysis

The Yolo Bypass lies within the boundaries of the Central Valley Joint Venture's (CVJV) Yolo Basin planning area (Figure 2). The CVJV's dabbling duck population objectives are developed for each of the major 'basins' within the Central Valley, including the Yolo Basin. To analyze the effects of altered flooding regimes on dabbling ducks, a series of linked models were used (Figure 3). Land cover information was combined with flood-depth model results (Figure 4) and input into the Bypass Depth (BDepth) GIS model. This GIS model separated the depth of each land cover class into dry (0"), managed/shallow (≤18"), or deep (>18") water categories and performed that action for each date between October 1 and May 31 (Figure 5). Summations of the acre calculations from these outputs, in combination with the Yolo Basin's waterfowl population objectives, were then used in the TRUEMET Avian Bioenergetics Model for the Yolo Basin. Final output of this progression was food energy supply and food energy demand curves (Figure 6) that show how changes in flooding in the Yolo Bypass might affect the capacity for waterfowl habitats in the Bypass to provide adequate food resources for the waterfowl population in the Yolo Basin.

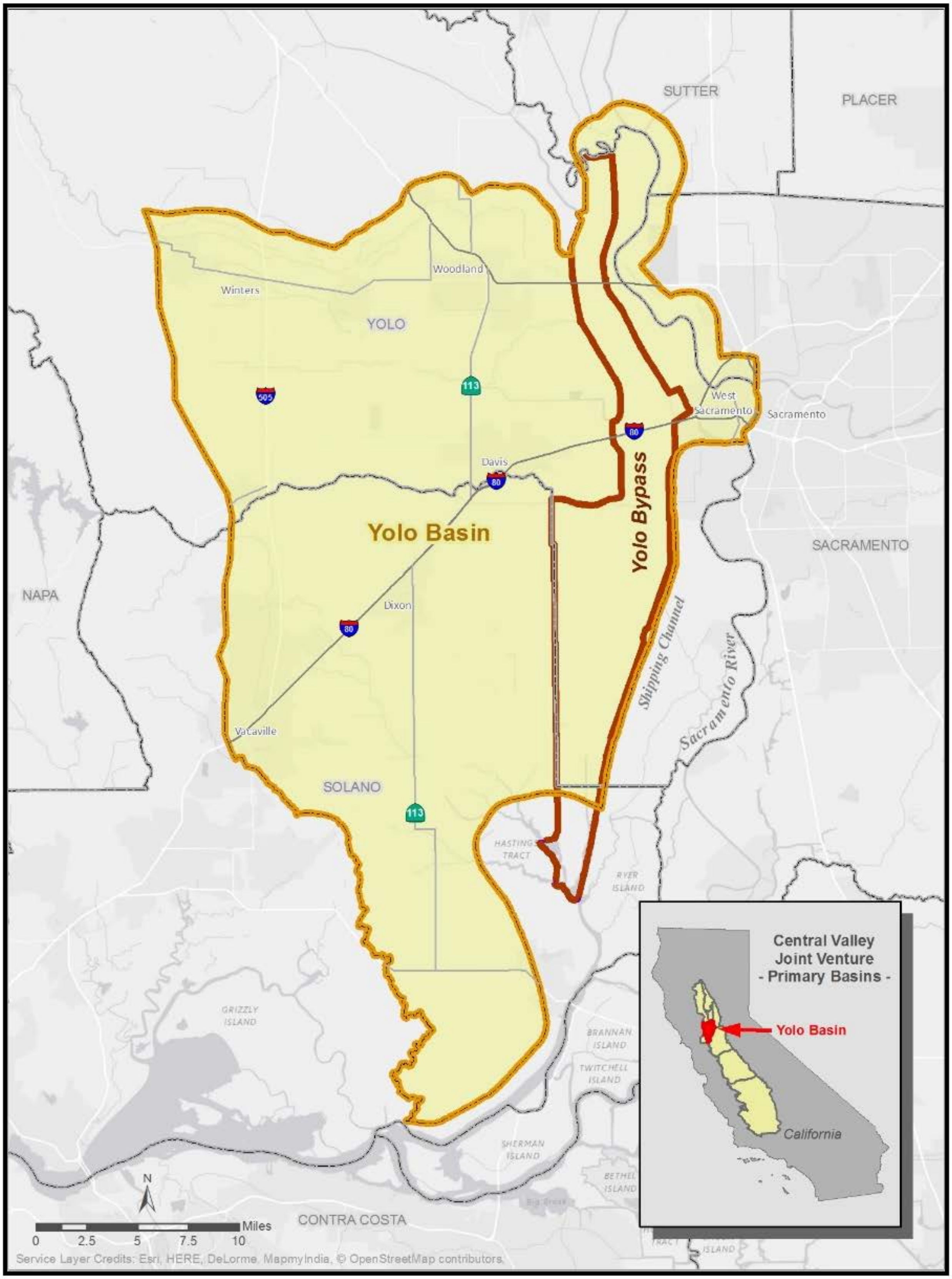


Figure 2. Location of the Yolo Bypass.

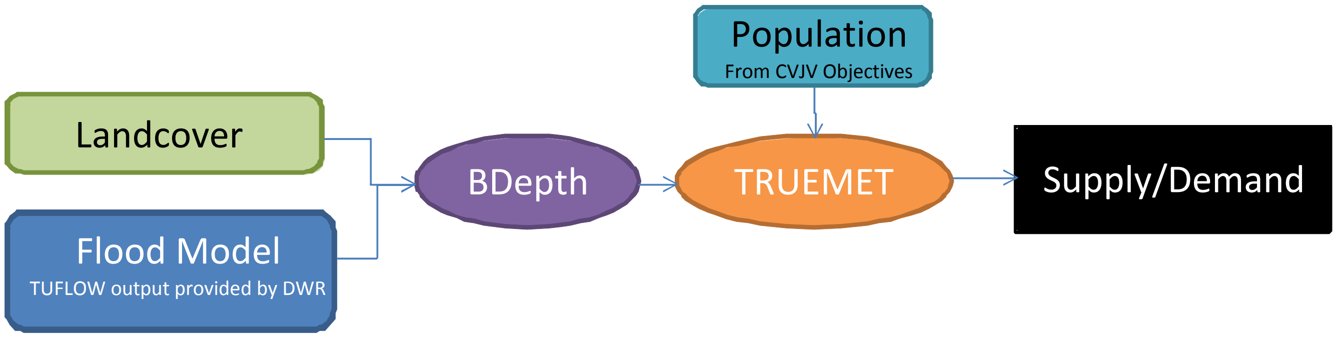


Figure 3. Data inputs and models used in the modeling of the loss of winter foraging habitat

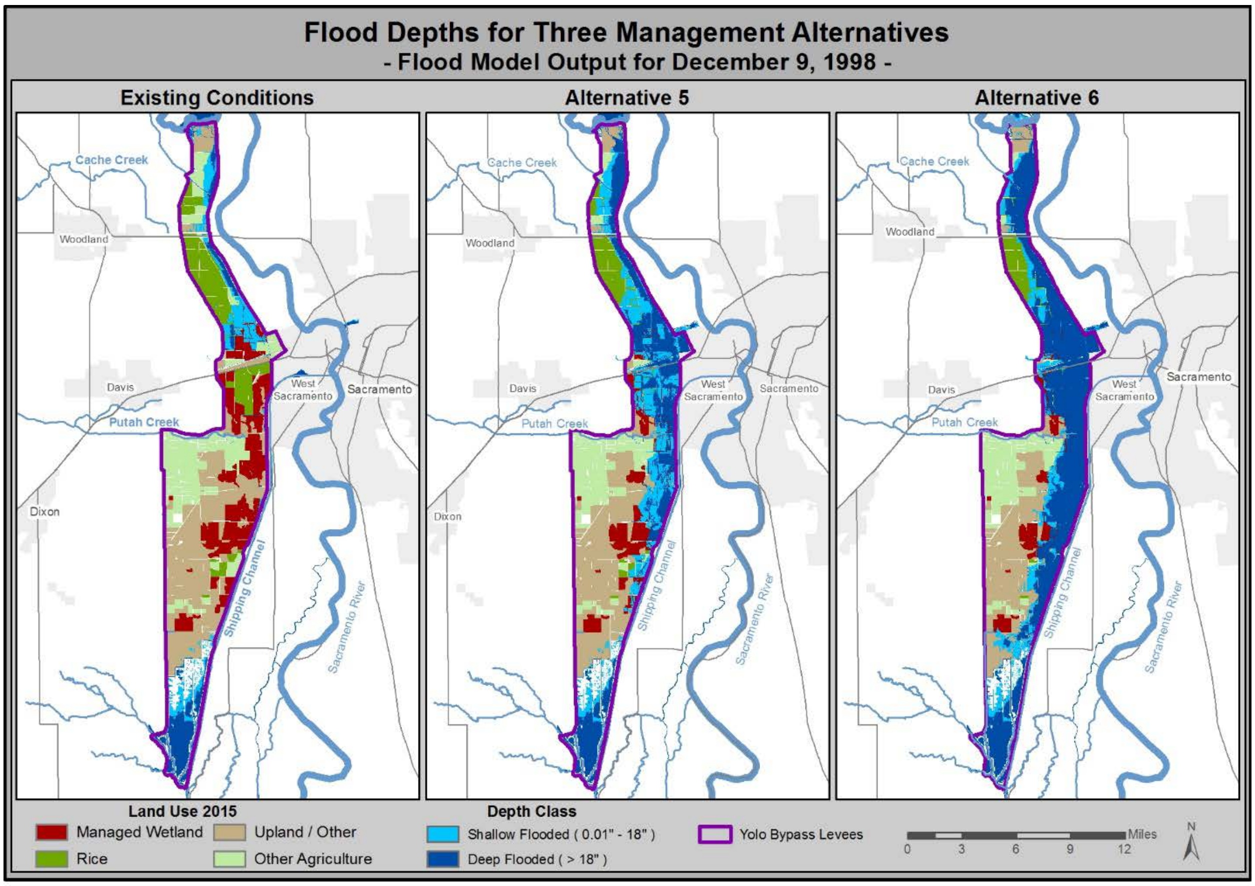


Figure 4. Example of a single day of flood depth model ouputs overlaid on land cover data. Although the Alternative 6 flooding pattern depicted here does not show the maximum flooding level (entire bypass flooded) experienced in the Bypass, it does represent the flooding pattern on the date where the maximum difference was observed in wetland acres between Existing Conditions and any Alternative in any of the three years evalutated.

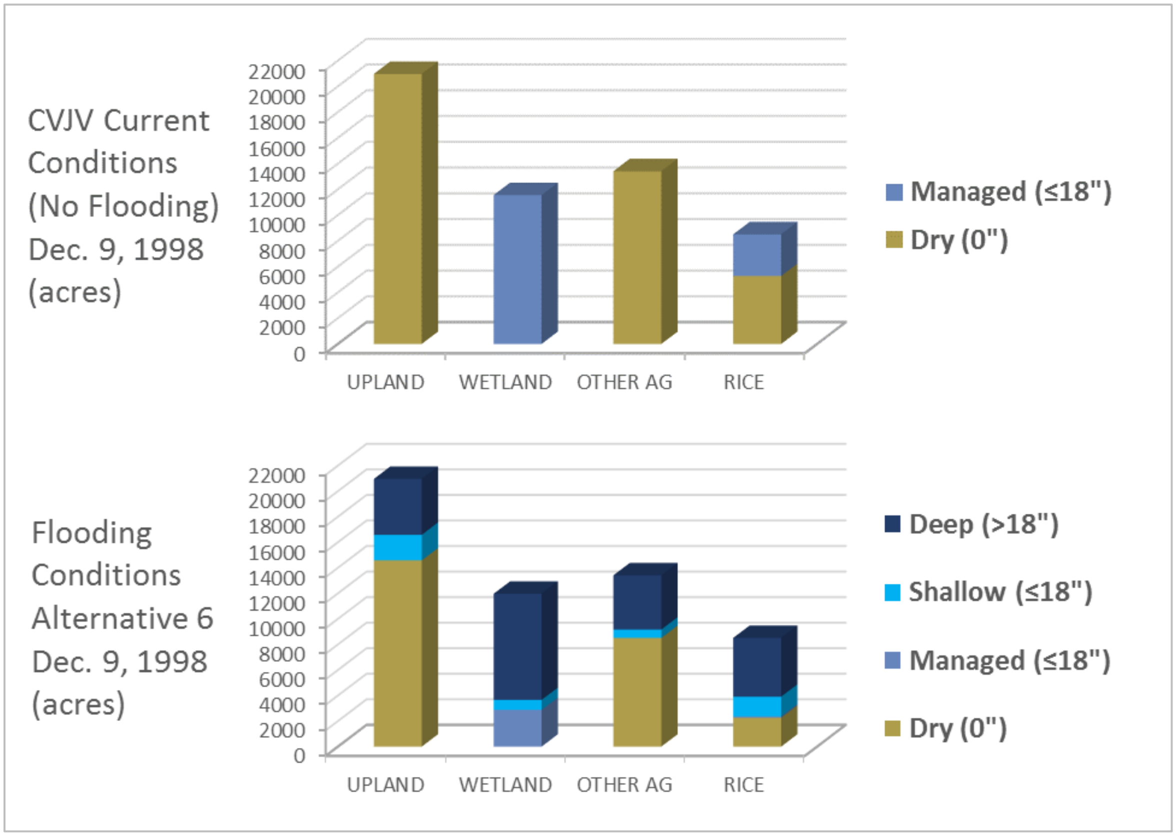


Figure 5. Graphic example of the acre calculation output from the BDepth model. This graphic compares data from a single day in water year 1999 to a year when no flooding occurs in the bypass.

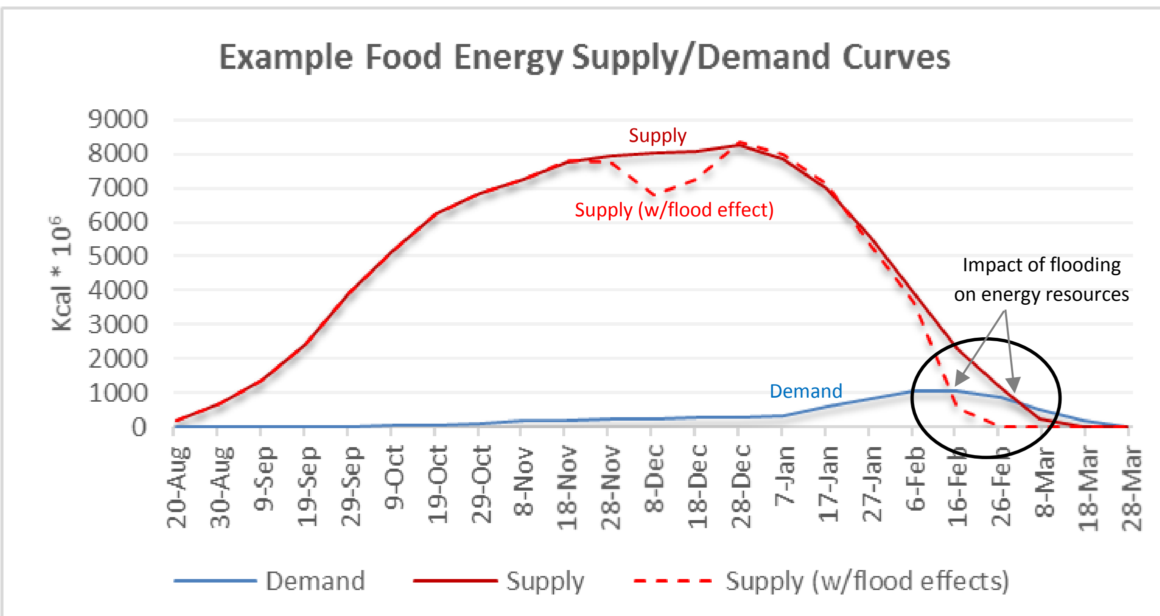


Figure 6. Example of food energy supply/demand curves output from TRUEMET model.

4 Methods

4.1 BDepth GIS Model

4.1.1 Land Cover Data

Land cover data for the analysis was provided by DWR. The data layer included crop information on a field level for all areas in the Yolo Bypass for a five year period from 2005 - 2009. Non-agriculture areas were labeled as either wetland or pastureland (upland). This was the same landcover layer used for other analyses conducted for the DWR's EIS/EIR report. Two changes were made to the dataset for this analysis. First, rice and corn are the only two crop types that are considered by the CVJV to have significant foraging value for wintering waterfowl in the Yolo Basin so the data layer was recoded to represent four cover types: Wetland, Upland (Pasture/Grassland), Rice, and Other Agriculture. There was no class for Corn because only a single agricultural field was labeled as corn in only one of the five years. Since that field was planted to other crops in all other years it was grouped with the Other Agriculture class. Additionally, because agricultural crops grown in an individual field can vary from year to year based on market prices and other factors, only fields that were planted to rice in at least 3 out of the 5 years were labeled as Rice in the layer used for the final analysis. The second change in the land cover layer was made in the Wetland class. The intent of this analysis is to address impacts to the current conditions of waterfowl habitat in the Yolo Bypass. Several wetland restorations and enhancement projects have occurred within the Bypass between 2009 (the most recent year represented in the original land cover layer) and 2016, so these restored/enhanced wetland areas were relabeled to Wetland in the final landcover layer (Figure 7).

4.1.1 TUFLOW Model Flood Depth Data

DWR provided modeling results from the TUFLOW© Flood and Coastal Simulation Software (TUFLOW), (BMT Group Ltd., United Kingdom) for a 16-year period of analysis (1997 – 2012) for each of the five alternatives analyzed. The TUFLOW output provided the patterns of inundation and depth throughout the Bypass on a daily basis between October 1 and May 31. The data was provided in NetCDF data format and imported into ESRI ArcGIS software using the Make NetCDF Raster tool.

4.1.2 BDepth Model

The BDepth model is a custom Python script tool written specifically for this project that runs within ESRI ArcGIS software. The tool automated the iterative process of:

1) importing a single date of flood inundation data from a NetCDF file into ArcGIS raster format;
2) recoding the depth layer into a 3-class layer representing dry, shallow-flooded, and deep-flooded areas;
3) clipping the 3-class depth layer to the extent of the land cover layer;
4) overlaying the flood and landcover layers using the "Union" command;
5) calculating the acres of each land cover type and flood depth combination;
6) outputting the acreage data to a text file; and
7) looping through this process for all 242 days (Oct 1 – May 31) in a given water year.

This tool was run 15 times, once for each alternative in each of the three evaluated water years. The output produced a text file containing the number of acres of each land cover class in each of the three depth classes for each day of that water year. These acre calculations were then used as input to the TRUEMET energetics model.

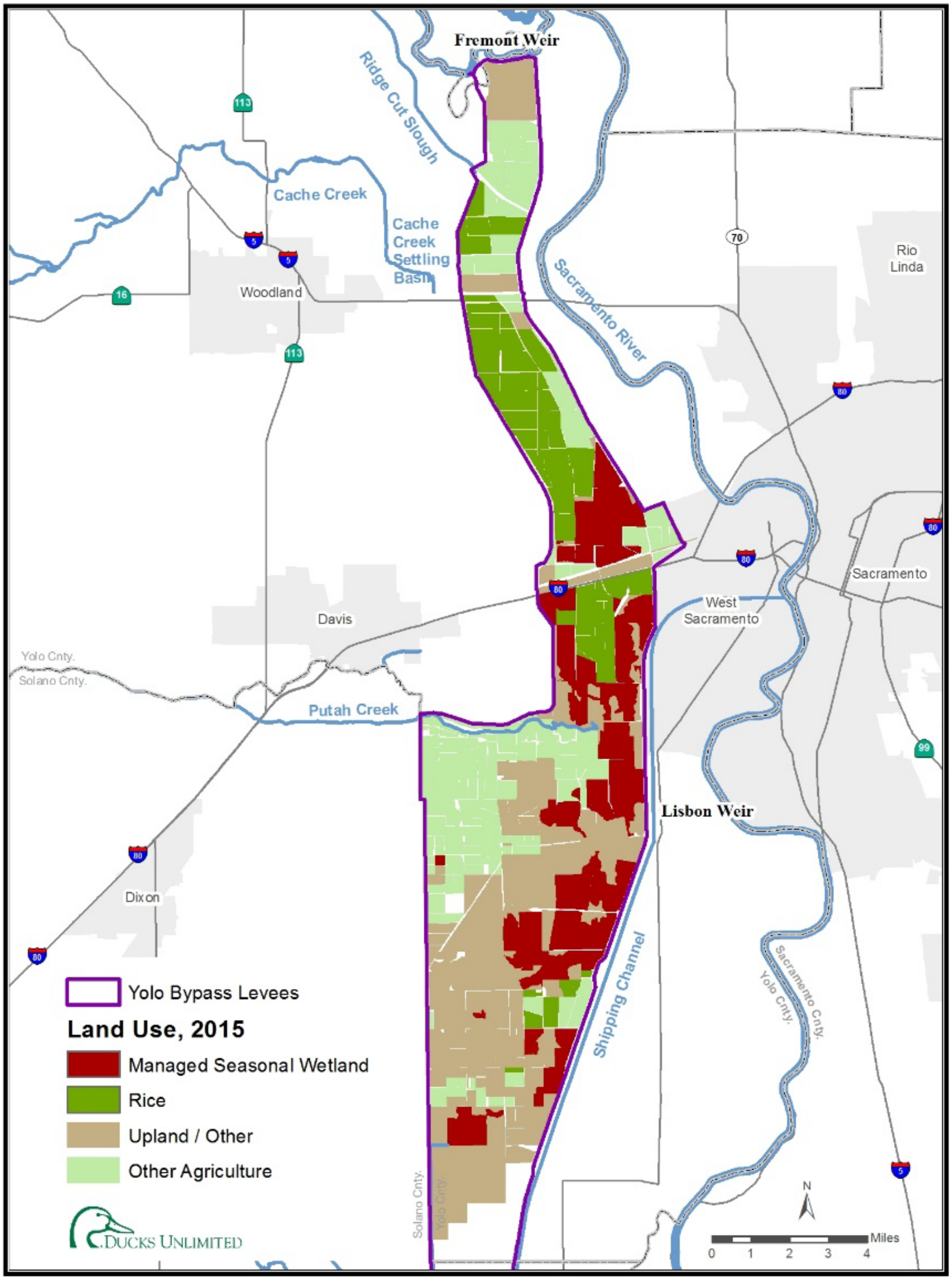


Figure 6. Land cover layer used for this analysis.

4.2 TRUEMET Energetics Model

Conservation planning for waterfowl in the Central Valley is the responsibility of the Central Valley Joint Venture (CVJV). The CVJV has divided the Central Valley into nine drainage basins that serve as planning units, including the Yolo Basin. Conservation and habitat objectives are established at the drainage basin scale, and the biological assumptions and data used to develop these objectives are fully described in the CVJV's implementation plan (CVJV 2006). Although this effects analysis is focused on management alternatives that are specific to the Yolo Bypass, our analysis was conducted at the larger scale of the Yolo Basin itself. We believe that the CVJV's planning approach provides the best context for evaluating these management alternatives; however, this requires us to report model results at the drainage basin scale. Moreover, the CVJV has established waterfowl population objectives at the drainage basin scale and these objectives cannot be distilled to smaller scales like the Yolo Bypass.

Conservation planning for migrating and wintering waterfowl in the Central Valley, and by extension the Yolo Bypass, is largely driven by the food limitation hypothesis which states that food availability during the non-breeding period influences survival and reproductive success through its effects on body condition (Williams et al. 2014). The fundamental assumption is that by providing adequate food and reducing energetic costs during fall and winter, birds will maintain good body condition, overwinter survival will be high and birds returning to the breeding grounds will be in good condition and may be more successful in reproduction.

Waterfowl in the Central Valley experience considerable variation in habitat availability from fall through spring. As a result, the CVJV used the daily ration model TRUEMET to evaluate landscape conditions and establish conservation objectives for non-breeding waterfowl (Petrie et al. 2016). TRUEMET allows the user to define when foraging habitats become available within the time period being modeled. As a result, the relationship between population energy demand and energy supply can be examined for any point in time for multiple foraging guilds, and exploitive competition for food resources among foraging guilds can be accounted for (e.g., the effects of goose consumption on dabbling duck food resources is accounted for in all period-specific estimates of dabbling duck energy supply). There are eight explicit inputs required for each TRUEMET model run: 1) number of days or time periods being modeled within the overall season of interest, 2) population objectives or estimates for each waterfowl foraging guild within each time period, 3) daily energy expenditure of a single bird in each foraging guild within each time period, 4) habitat types used by each waterfowl foraging guild to satisfy daily energy requirements, 5) area and availability of habitat types during each time period, 6) biomass of food in each habitat type at the start of the overall season of interest, 7) nutritional quality (i.e., true metabolizable energy content) and 8) decomposition rate of each food type. Implementation of any alternative proposed by the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project would specifically affect input #5 (above), the area and availability of habitat types during each time period. The Project could potentially affect input #6, the biomass of food in each habitat type, if the various flooding regimes alter plant species composition and/or the quality and quantity of seed production within managed wetland habitats in subsequent years. The analysis conducted under this task order only addresses the impacts to model input #5.

Within TRUEMET, the Total Energy Demand (TED; in kcal) of a foraging guild in a time period is calculated as:

$$TED_{jk} = POP_{jk} \times D_k \times DEE_{jk}$$

where TED_{jk} = total energy demand of foraging guild j in time period k, POP_{jk} = population size of foraging guild j in time period k, D_k = number of days in time period k, and DEE_{jk} = daily energy expenditure (kcal) of an average bird in foraging guild j in time period k. The Total Energy Supply (TES; in kcal) available to a foraging guild in a time period is calculated as:

$$TES_{jk} = \sum_{i=1}^{n} NEFH_{ijk}$$

where TES_{jk} = total energy supply available to foraging guild j in time period k, and $NEFH_{ijk}$ = net energy available in foraging habitat i to foraging guild j at the beginning of time period k. This equation assumes that foraging guild j has been given access to foraging habitat i within the model.

The TRUEMET model requires the user to identify the maximum area of foraging habitat (FH_i) possible within the time frame being modelled. This habitat is placed in a "reservoir" where it can be made available incrementally over time by the user, including releasing all of it in a single time period. For example, managed wetlands can be released from the reservoir at a rate that reflects their flooding schedule. Conversely, foraging habitats can be retrieved by the model and placed back in the reservoir where they are no longer available to the birds (e.g., where managed wetlands become deeply flooded and the food resources in these habitats cannot be accessed). The rate at which a foraging habitat is released from the reservoir or retrieved is dependent on user inputs that define the availability of this foraging habitat over the time (i.e., the user builds "availability curves" within the model). Thus, $NEFH_{ijk}$ is a function of the cumulative sum of food energy released from the reservoir prior to and including time period k, the cumulative sum of waterfowl food consumption and food decomposition that occur in time periods prior to k, and the cumulative energy of foraging habitat i returned to the reservoir in time periods prior to k (e.g. due to drying conditions). The model calculates $NEFH_{ijk}$ as follows:

$$NEFH_{ijk} = \left\{ \sum_{k=1}^{k-1} \left[EFH_{ijk} - CFH_{ik} - DFH_{ik} - R_{ik} \right] \right\} + EFH_{ijk}$$

where EFH_{ijk} is the energy of foraging habitat i released from the reservoir at the beginning of time period k to which foraging guild j has access, CFH_{ik} = total consumption of food energy in foraging habitat i during time period k, DFH_{ik} = decomposition of food energy in foraging habitat i during period k, and R_{ik} = energy of foraging habitat i returned to the reservoir at the end of time period k (e.g., due to drying conditions). The model calculates EFH_{ijk} as follows:

$$EFH_{ijk} = FBFH_i \times MEFH_i \times HFH_{ijk}$$

where $FBFH_i$ = the food biomass per unit area of FH_i that resides in the reservoir (i.e. starting condition), $MEFH_i$ = the true metabolizable energy (e.g., kcal/g) of foods provided by FH_i, and HFH_{ijk} = area of FH_i released from the reservoir at the beginning of period k to which guild j has access. TRUEMET calculates CFH_{ik} as follows:

$$CFH_{ik} = \sum_{j=1}^{n} \frac{NEFH_{ijk}}{TES_{jk}} \times \min(TED_{jk}, TES_{jk})$$

where CFH_{ik}= consumption of food energy in foraging habitat i in period k by all guilds having access to habitat i. Finally, TRUEMET calculates DFH_{ik} as follows:

$$DFH_{ik} = TEFH_{ik} \times DRFH_{ik}$$

where DFH_{ik} = decomposition of food energy (kcal) in foraging habitat i in period k, $TEFH_{ik}$ is the total energy of foraging habitat i that exists outside the reservoir in period k, and $DRFH_{ik}$ is the decomposition rate applied to the food in foraging habitat i in period k expressed as a fraction.

The equation for CFH_{ik} illustrates an important assumption of the model. For each time period, birds in a foraging guild are assumed to consume a food in proportion to its availability where availability is defined in energetic terms. For example, assume that birds in a duck guild are given access to managed wetlands and that this foraging habitat provides forty percent of all the food energy available to ducks in time period k. Within time period k, ducks would meet forty percent of their food energy needs from managed wetlands (if $TED_{jk} \geq TES_{jk}$) then the food resources provided by managed wetlands would be completely exhausted within time period k, though this foraging habitat could provide food energy in future time periods if additional managed wetlands were made available in these future periods).

The assumption that foods are consumed in proportion to their contribution to total food energy may be violated in some model scenarios. Birds may show some selection in the foods they eat, and thus deplete some foods at a faster or slower rate than what would be predicted by relative energy abundance alone. Most applications of the model are more concerned with the total energy available to a guild in each time period, as opposed to accurately predicting how quickly a given foraging habitat is depleted. The biological assumption is that birds will switch to less favored foods as more desired foods are depleted. However our ability to accurately model food energy for each foraging guild using TRUEMET is strongly dependent on our understanding and assumptions about how foraging guilds overlap in their use of habitats and the exploitive competition for food resources that result from this overlap. Thus, careful consideration must be given about the habitats that are assumed to be used by each foraging guild.

TIME PERIODS.

Migrating and wintering waterfowl are present in the Central Valley from mid-August through the end of March. As a result, we modeled waterfowl population energy demand and food energy supply for the Yolo Basin at ten-day intervals between August 16 and March 31.

Waterfowl guild population objectives and estimates. The CVJV now recognizes two foraging guilds, ducks and geese, and these same foraging guilds were used for here. Approximately 92% of all ducks are dabbling ducks, whereas the remainders are diving ducks. Diving ducks were pooled with dabbling ducks in the TRUEMET model to account for their potential competition for food resources with dabbling ducks, especially wetland plant seeds in managed seasonal wetlands. The goose guild includes white-fronted geese, lesser snow geese, Ross's geese, western Canada geese, Aleutian cackling geese, and Tundra swans. The majority of geese using the Yolo Basin are white-fronted geese, lesser snow geese, and Ross's geese.

Duck population objectives for each 10-day interval represent the number of birds that are expected to winter in the Yolo Basin when continental breeding duck populations are at NAWMP goals. Population objectives for the Central Valley as a whole were first "stepped down" from the NAWMP and then divided among the CVJV's nine drainage basins based on an understanding of bird distribution in the Central Valley. Five percent of the Central Valley duck population objective was assigned to the Yolo Basin (CVJV 2006). This equates to approximately 30.4 million duck-use-days or DUD's, where one DUD equates to a single duck residing in the Yolo Basin for one day. However, transforming these DUD's into 10-day population objectives requires an understanding of duck migration chronology within the Yolo Basin. We used information on duck migration chronology specific to the Yolo Basin (Fleskes et al. 2005) to establish these 10-day population objectives using the same approach adopted in the 2006 CVJV Implementation Plan (CVJV 2006). This resulted in population objectives that were highest in late winter-early spring, and reflected the Fleskes et al. (2005) study that reported high bird numbers in the Yolo Basin during these latter time periods (Table 1). Duck numbers in the Central Valley as a whole peak in late December-early January after which they decline (CVJV 2006). As a result, we also established 10-day population objectives for the Yolo Basin based on duck migration chronology for the Central Valley as a whole (Table 1). This set of alternative population objectives was used in some model scenarios to examine how robust our results were to different assumptions about migration chronology, which undoubtedly varies from year to year. These alternative population objectives still equated to 30.4 million DUDS's, but represent a different temporal pattern of bird use of the Yolo Basin from mid-August through March.

Many North American goose populations have exceeded their population objectives and Joint Ventures have been advised to use recent goose counts when developing implementation plans (Koneff 2003). As a result, we used recent counts of geese in the Central Valley (Olson 2015) and information on migration chronology (Fleskes et al. 2005) to estimate the number of geese in the Yolo Basin for each 10-day period between mid-August and late March. Although our effects analysis is focused on ducks, not geese, it is important to account for the effects of goose consumption on duck food resources in the Yolo Basin.

Ten-Day Period	Population Objective[a]	Population Objective[b]
Aug 20	1,346	18,045
Aug 30	2,788	35,406
Sept 9	3,558	43,021
Sept 19	4,386	51,117
Sept 29	7,000	70,812
Oct 9	13,755	94,325
Oct 19	29,166	115,508
Oct 29	50,544	131,345
Nov 8	73,584	145,903
Nov 18	94,755	162,928
Nov 28	108,821	188,348
Dec 8	118,636	212,690
Dec 18	124,838	224,832
Dec 28	126,628	223,856
Jan 7	143,521	214,779
Jan 17	231,951	198,394
Jan 27	316,169	182,740
Feb 6	397,999	167,511
Feb 16	467,338	152,225
Feb 26	384,707	135,630
Mar 7	235,821	188,259
Mar 17	78,667	98,678
Mar 27	5,015	15,607

[a] Ten-day duck population objectives for the Yolo Basin based on the CVJV's current assumptions about duck migration chronology for the Yolo Basin.

[b] Ten-day duck population objectives for the Yolo Basin based where duck migration for the Yolo Basin is assumed to be the same as for the Central Valley as a whole.

Table 1. Ten-day duck population objectives represented under two different migration chronologies.

Daily Energy Expenditure

The daily energy expenditure (DEE) of geese and swans was estimated by multiplying the resting metabolic rate (RMR) of an "average" bird by a factor of three to account for the energy costs of free living (Williams et al. 2014). We used the following equation from Miller and Eadie (2006) to calculate the RMR for geese and swans:

$$\text{Geese and Swans RMR } (kJ \text{ / day}) = 419 * (\text{body mass in kg})^{\,0.719}$$

Body mass estimates were for geese and swans were obtained from Bellrose (1980), and adult weights were used to avoid underestimating DEE. The relative abundance of species included in the goose foraging guild varied by time period. As a result, we calculated a weighted body mass for all time periods. Finally, we converted kJ to kcal by dividing the latter by 4.18 .

The CVJV did not use an estimate of RMR to estimate DEE for ducks. Instead, they relied on Miller and Newton's (1999) period specific estimates of DEE for pintails between August and March that were derived from pintail body mass and carcass composition. We adopted those values here. Weighted body mass for ducks in the Central Valley is 0.84 kg. This is similar to pintails (0.92 kg), which make up **46%** of the CVJV duck population objective (CVJV 2006).

Foraging Habitat Area and Availability

The CVJV assumes that ducks in the Central Valley rely on three major foraging habitats, including managed seasonal wetlands, harvested rice fields that are winter-flooded, and harvested grain corn fields that are flooded and unflooded (CVJV 2006). We adopted the same assumptions for ducks that utilize the Yolo Basin. Geese were assumed to forage in harvested rice fields and harvested grain corn fields regardless if they are flooded, and believed to use wetlands mostly for roosting purposes. The area of each of these habitat types in the Yolo Bypass and Yolo Basin as a whole is presented in Table 2.

Habitat Type	In Bypass	Outside Bypass	Total
Managed Wetland	11,554	0	11,554
Winter-Flooded Rice	5,277	7,671	12,948
Unflooded Rice	2,426	3,526	5,952
Corn	0	2,512	2,512
Total	19,257	13,709	32,966

Table 2. Acres of foraging habitat in the Yolo Basin.

Temporal variation in habitat availability can strongly influence the food supplies available to ducks and geese. As a result, we incorporated the CVJV's current assumptions about the temporal availability of important waterfowl habitats in the Yolo Basin. In general, flooding of managed seasonal wetlands begins in late August with all wetlands flooded by late November. These wetland habitats remain flooded through March, after which they are drawn-down (de-watered) to promote the growth of moist-soil plant species during late spring and summer. Harvest of rice and grain corn generally begins in early September and is complete by late October to early November. For harvested rice fields that are winter-flooded, flooding begins in late September and peaks by mid-winter after which the amount of winter-flooded rice declines steadily through March (CVJV 2006, Petrie et al. 2016).

Biomass, nutritional quality, and decomposition rates of waterfowl food types

We used waterfowl food biomass estimates for managed seasonal wetlands and harvested grain corn fields presented in the CVJV Plan (2006), but updated those estimates for rice habitats on the basis of more recent information (Fleskes 2012). We also slightly adjusted food biomass estimates for managed seasonal wetlands after reviewing the study on which these estimates were based (Naylor 2002). The nutritional quality, or true metabolizable energy, of waterfowl foods was also taken from the CVJV Plan. We also used estimated decomposition rates for seeds in managed wetlands and rice and corn fields from the CVJV Plan, which are based on earlier work by Nelms and Twendt (1996) and Naylor et al. (2002).

Although seed production from moist soil plants accounts for most of the food energy available to ducks in managed seasonal wetlands, invertebrates can make up 25% of the diet from January through March (Euliss and Harris 1987). To recognize the potential importance of invertebrates during late winter, the CVJV assumes that managed seasonal wetlands provide 31 kg/ha beginning January 1 (CVJV 2006). This estimate is based on late winter estimates of invertebrate biomass for seasonal wetlands in the Mississippi Alluvial Valley (Manley 1999;).

Model Scenarios

To evaluate the effects of the Project on duck food supplies in the Yolo Basin we first modeled the relationship between duck population energy demand and food energy supply in a manner that reflected the CVJV's current assumptions about habitat availability in the Yolo Basin (Current Conditions). Those conditions assume that managed seasonal wetlands, winter-flooded rice, and harvested grain corn fields are all managed at water depths < 18, which allows ducks to fully exploit the food resources provided by these habitats (harvested grain corn fields that are not flooded are also assumed to be available to ducks as described above). Current conditions were modelled using the CVJV's existing assumptions about duck migration chronology in the Yolo Basin (Current Conditions MC 1) and where duck migration chronology was assumed to reflect that of the Central Valley as a whole (Current Conditions MC 2).

Under existing conditions of the Fremont Weir, the Yolo Bypass experiences varying levels and durations of flooding events in any given year, ranging from nearly no flooding in exceedingly dry years to complete flooding of the bypass for extended periods in exceedingly wet years. Assuming that impacts to waterfowl foraging availability may vary as a result of this natural variation in flooding events, we evaluated three historic water year conditions that represent a wet water year (1999) a dry water year (2002), and an above normal (wetter than normal) water year (2005).

In addition to modelling the relations between duck energy demand and food energy supply for each scenario, we also plotted how the acreage of managed seasonal wetlands ≤ 18 inches in depth (optimal foraging conditions for ducks) varied among scenarios between late August and late March (Figures 7 - 9). Managed seasonal wetlands contain the bulk of food resources available to ducks in the Yolo Basin (and the Yolo Bypass itself; see Results), and these differences in the availability of managed wetlands among scenarios offer a simple but direct view on how a given alternative impacts the principle food supply of ducks in the Yolo Basin. These same wetland habitats also provide for most of the hunting opportunity in the Yolo Basin, and can provide some insight into how duck hunting opportunities on public and privately managed wetlands may also be impacted by these alternatives.

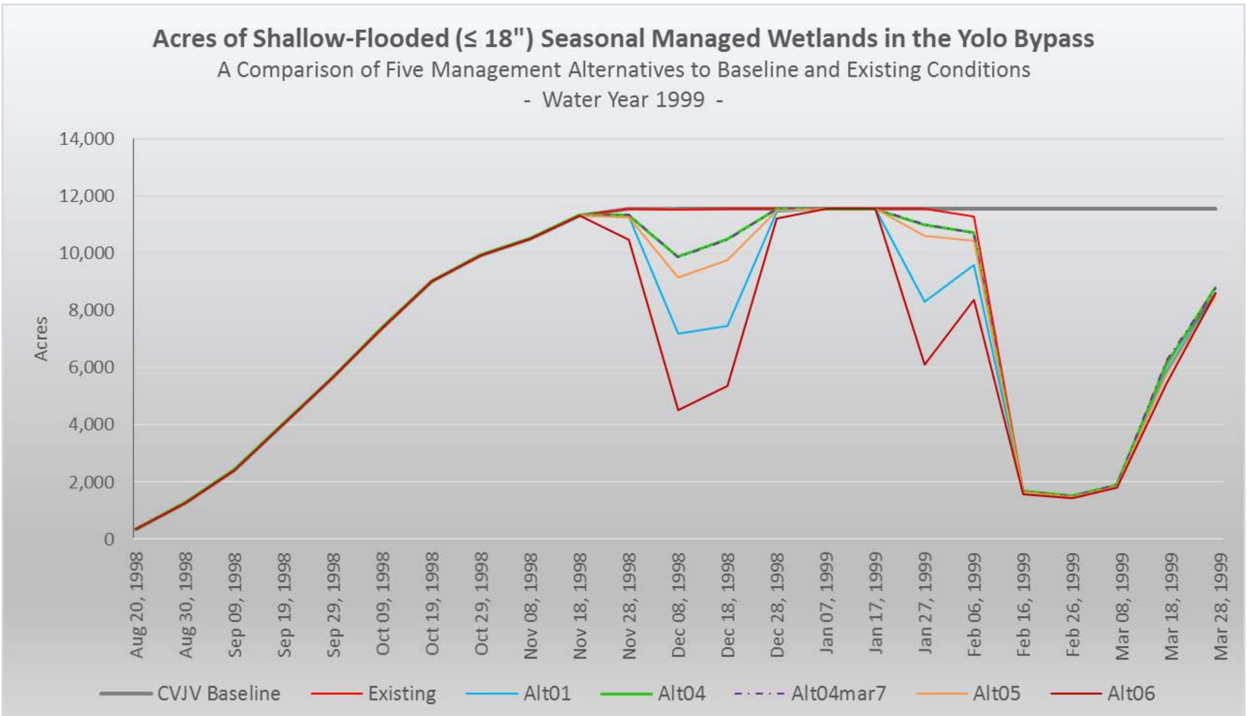


Figure 7. Average of number of acres of shallow-flooded (≤18") managed seasonal wetlands on a 10-day period, used as inputs to calculate the TRUEMET supply curves for 5 alternatives, baseline, and existing conditions in water year 1999.

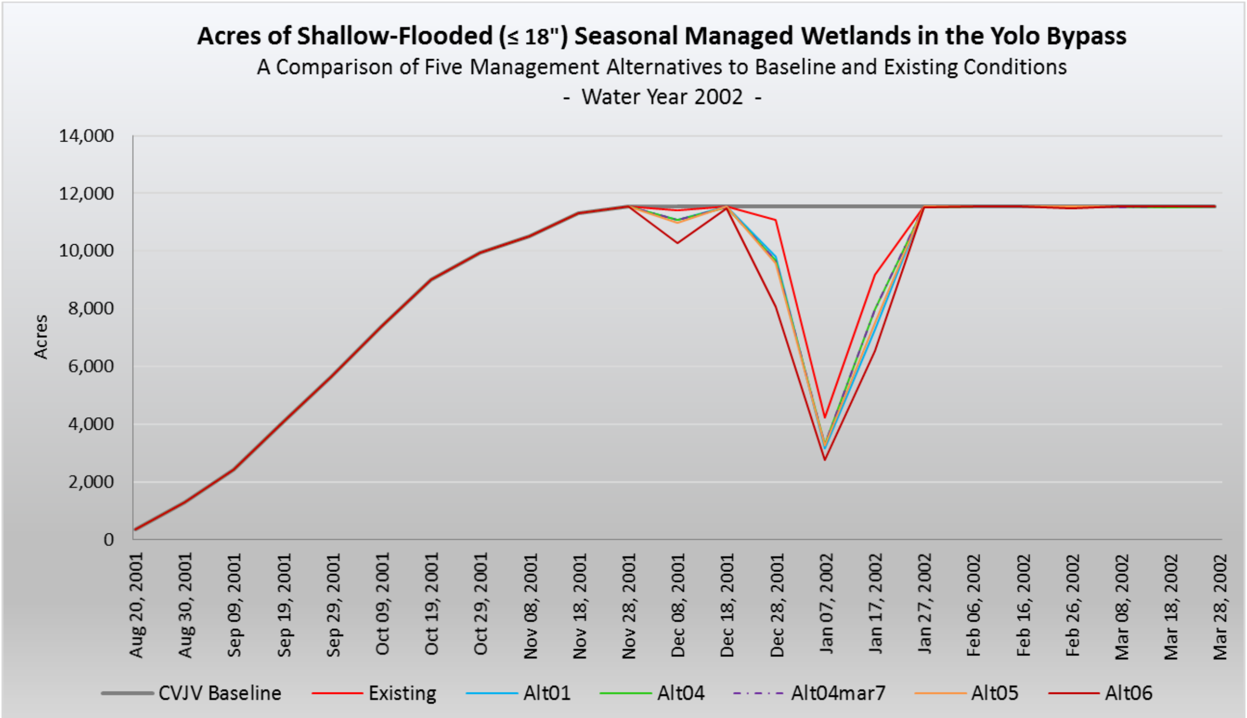


Figure 8. Average of number of acres of shallow-flooded (≤18") managed seasonal wetlands on a 10-day period, used as inputs to calculate the TRUEMET supply curves for 5 alternatives, baseline, and existing conditions in water year 2002.

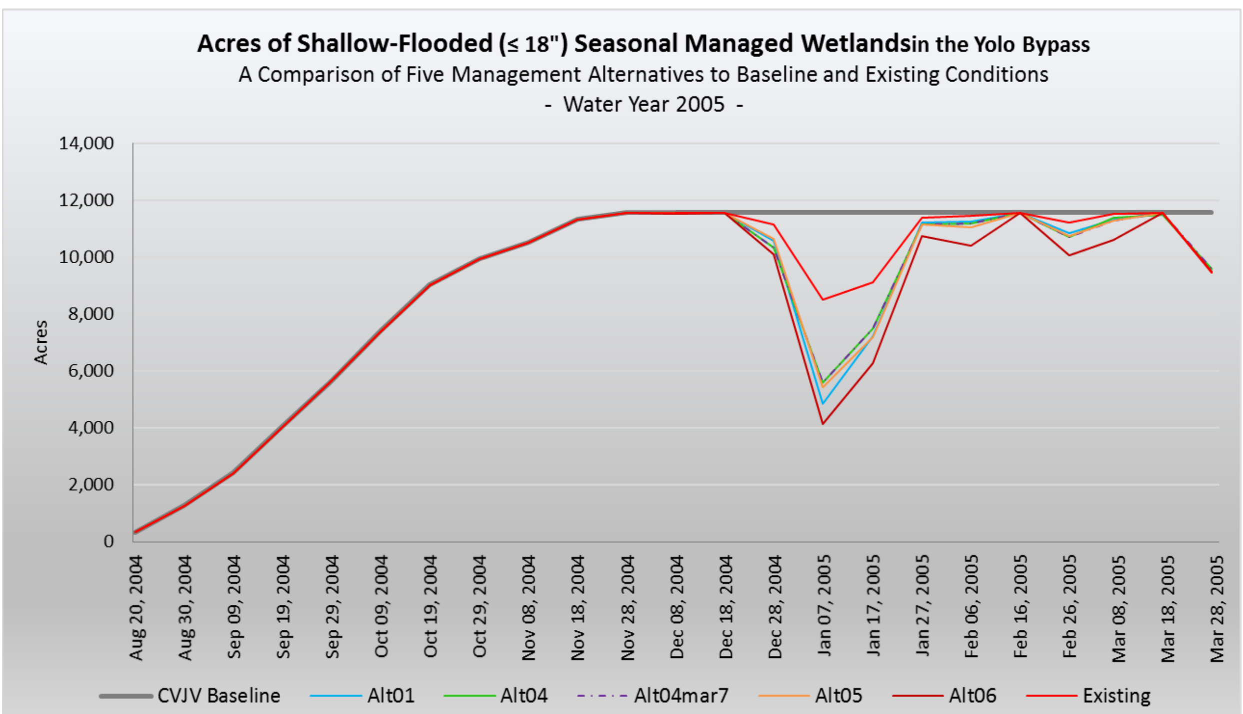


Figure 9. Average of number of acres of shallow-flooded (≤18") managed seasonal wetlands on a 10-day period, used as inputs to calculate the TRUEMET supply curves for 5 alternatives, baseline, and existing conditions in water year 2005.

5 Results

GIS BDepth Output

Appendix A, Tables 1-3 present a summary of the Bdepth GIS model output for each water year, showing the number of additional Acre-days and the average number of acres-per-day flooded in each land cover class under five management alternatives in comparison to existing conditions. Appendix A, Figures 1 and 2 present graphical representations of the acres of wetland and rice in each flooding depth class between October 1 and May 31. Note that the GIS analysis was run on the full 242 day (Oct 1 – May 31) TUFLOW dataset provided by DWR and these tables and figures represent that full dataset, whereas the TRUEMET analysis uses only the data between Oct. 1 through March 31 which represents the period of wintering waterfowl use in the Central Valley. Also note that the GIS analysis was run on existing conditions and five management alternatives. Alternative 4 with a March 7 operational cut-off was summarized by the GIS analysis, but was not examined under the TRUEMET analysis for waterfowl energetics. This alternative is identical to Alternative 4 except for the one-week period between March 7 -15, and was not expected to result in a significant difference in conclusions drawn from the TRUEMET analysis.

TRUEMET Analysis

The Yolo Basin provides approximately 27,000 acres of duck habitat in the form of managed seasonal wetlands, winter-flooded rice, and harvest grain corn fields (Table 1). Although nearly 40% of these acres occur outside of the Bypass, approximately 70% of the total food energy available to ducks in the Yolo Basin occurs within the boundaries of the Yolo Bypass. This is largely due to all managed seasonal wetlands being located in the Bypass (Table 1), and the high food density associated with these habitats. Within the Bypass itself, managed seasonal wetlands account for nearly 80% of all duck food resources.

Current Conditions MC 1 & MC 2

Duck food energy supplies in the Yolo Basin were insufficient to meet the duck population objectives established by the CVJV given the Joint Venture's current assumptions about migration chronology (MC 1) and habitat availability, as food supplies appear exhausted by early March (Figure 10). However, duck food supplies are predicted to be sufficient where migration chronology for the Yolo Basin is assumed to be similar to that of the Central Valley as a whole (MC 2; Figure 11).

1999 Existing Conditions and Alternatives

For Existing Conditions, duck food energy supplies were insufficient to meet population energy demands by mid-February regardless of what migration chronology we assumed (Figures 12 and 13). This exhaustion of duck food resources occurred approximately two weeks earlier than that predicted for the Current Conditions MC 1 scenario (Figure 10). In general, Alternatives 1, 4, 5, and 6 all predicted that duck food supplies would be exhausted by mid-to late February regardless of migration chronology (Figures 14-21); however, these alternatives did differ in terms of their impacts of duck food resources during the December periods. For example, Alternatives 1 and 6 produced steep declines in food energy supply during December compared to Existing Conditions (Figures 14 and 20 vs. 12), while Alternatives 4 and 5 (Figures 16 and 18) produced only modest declines during this month. In general, our choice of migration chronology had little effect on the overall relationship between Supply and Demand for any 1999 scenario.

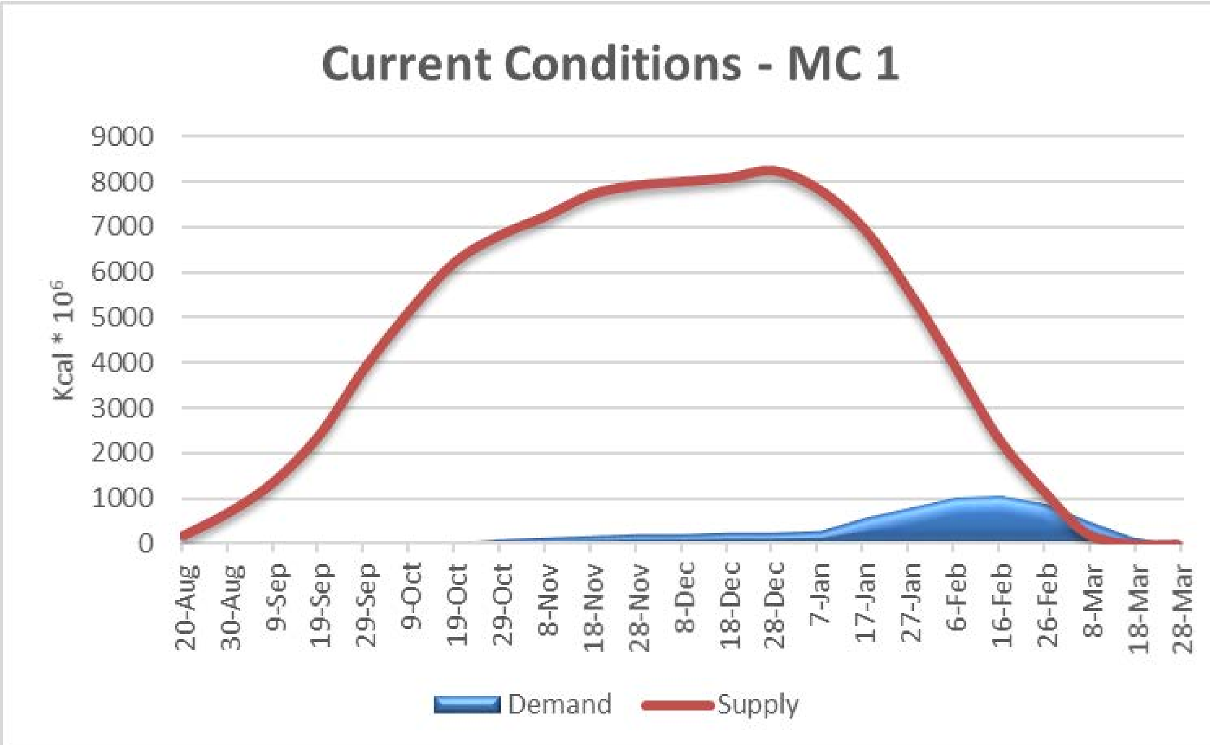


Figure 10. Duck food energy supply and demand curves for migration chronology 1 (Late-winter Peak).

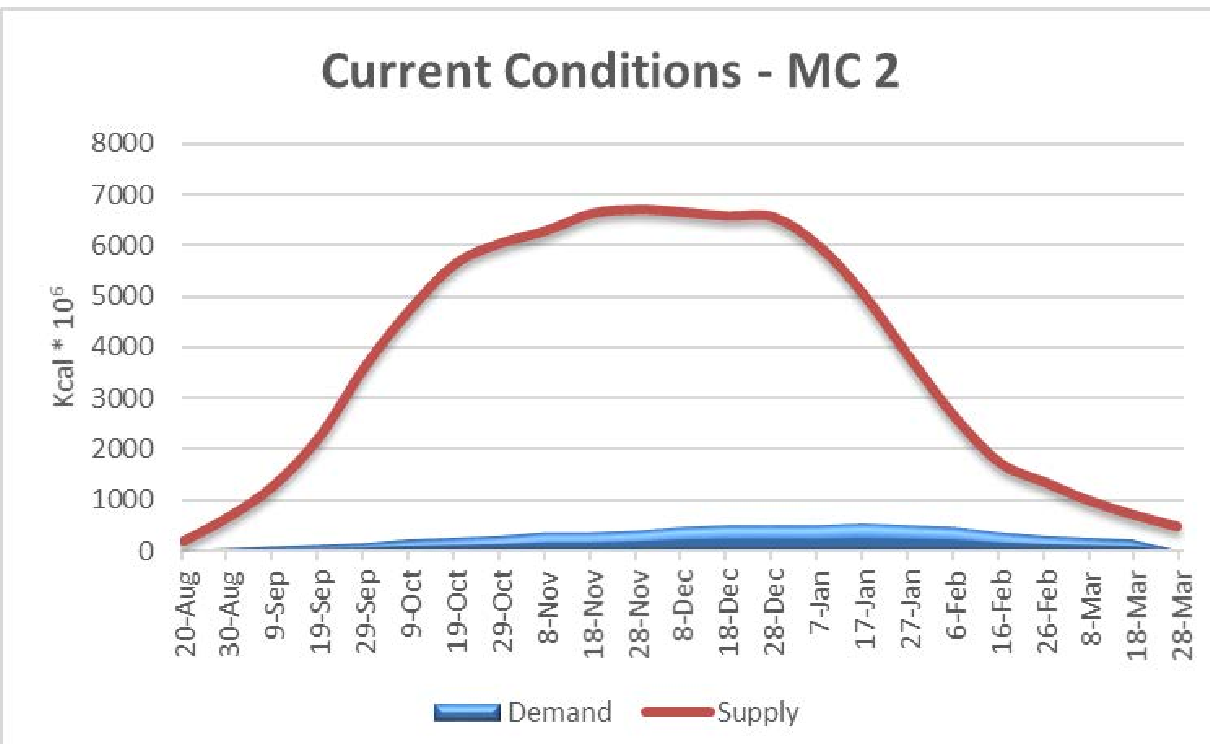


Figure 11. Duck food energy supply and demand curves for migration chronology 2 (Mid-winter Peak).

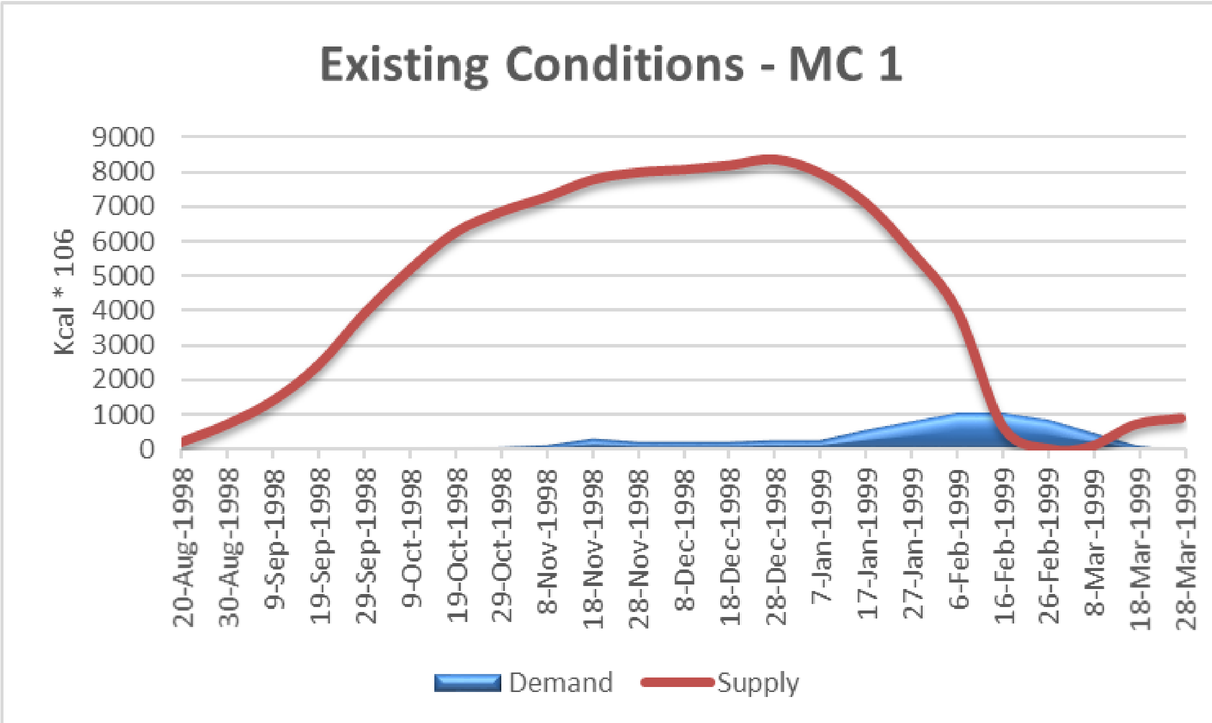


Figure 12. Duck food energy supply and demand curves: 1999, Existing MC 1 (Late-winter Peak).

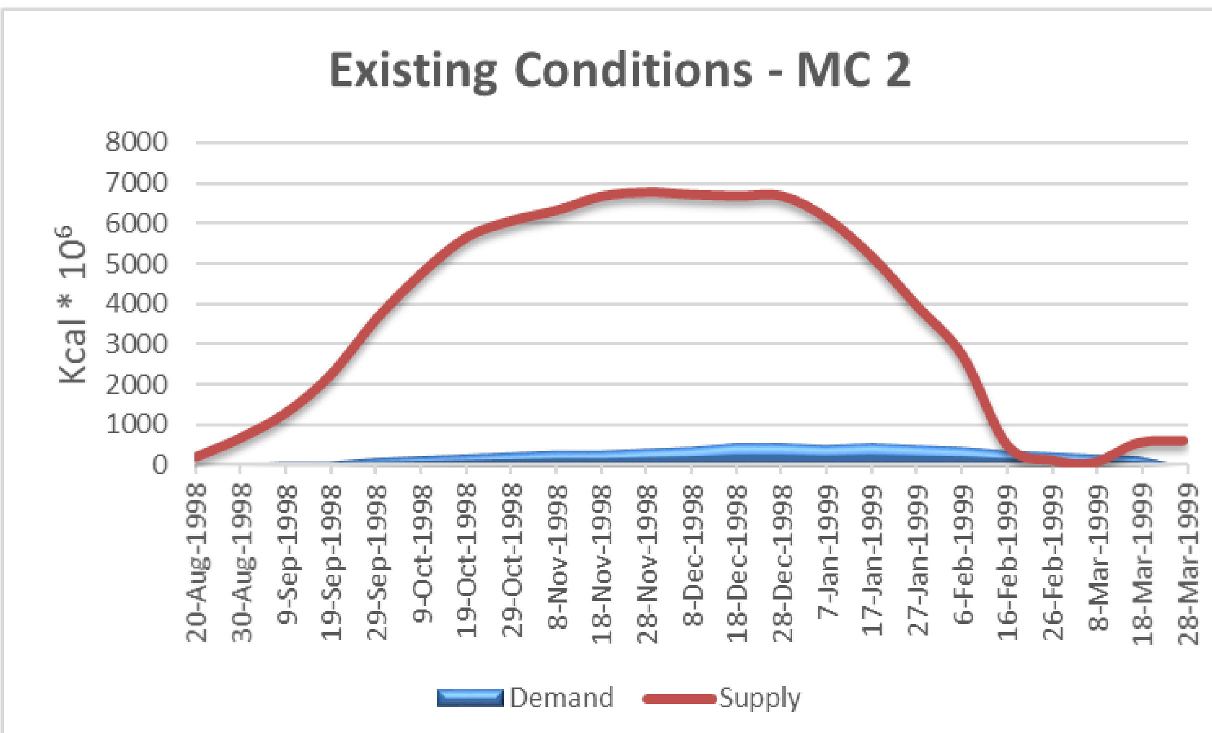


Figure 13. Duck food energy supply and demand curves: 1999, Existing MC 2 (Mid-winter Peak).

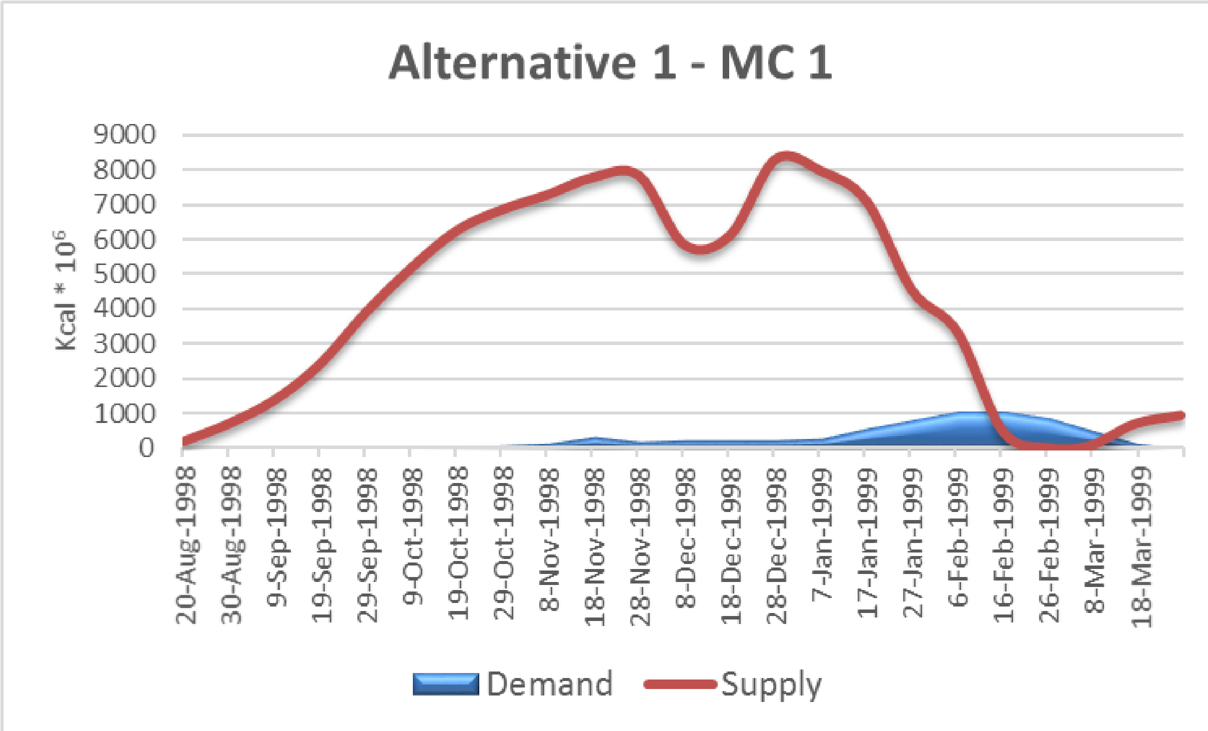


Figure 14. Duck food energy supply and demand curves: 1999 Alternative 1, MC 1 (Late-winter Peak).

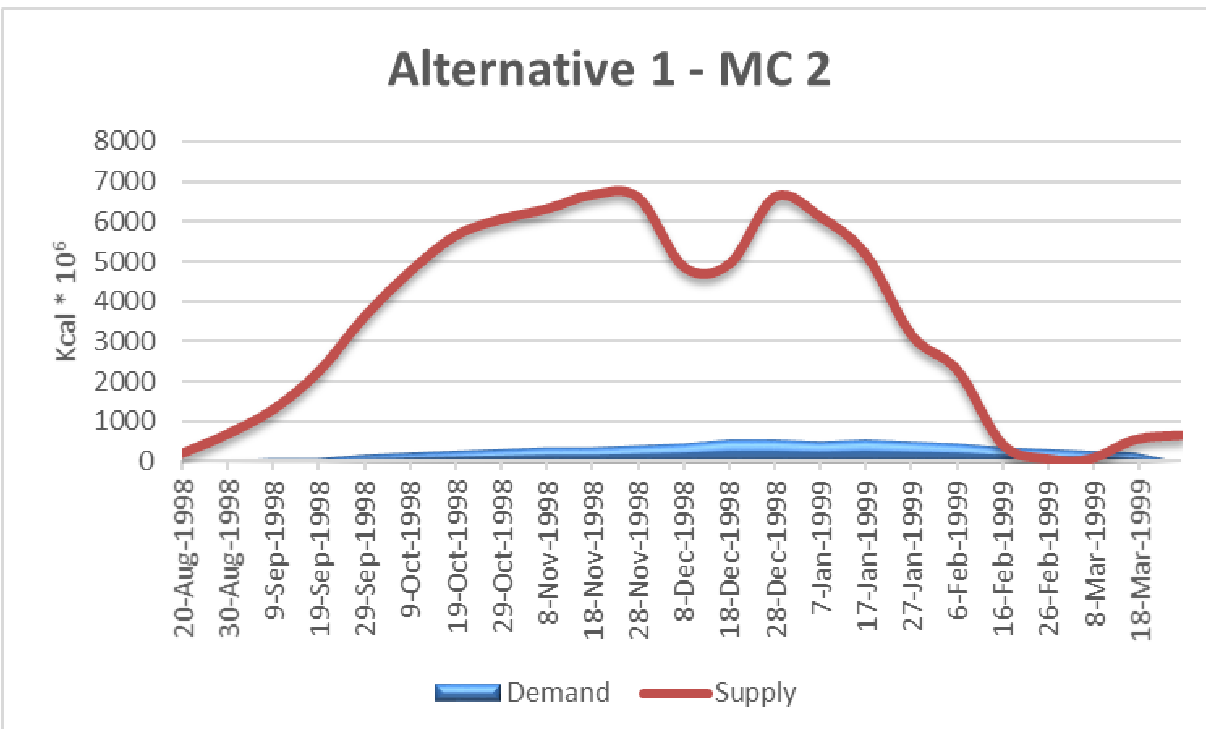


Figure 15. Duck food energy supply and demand curves: 1999 Alternative 1, MC 2 (Mid-winter Peak).

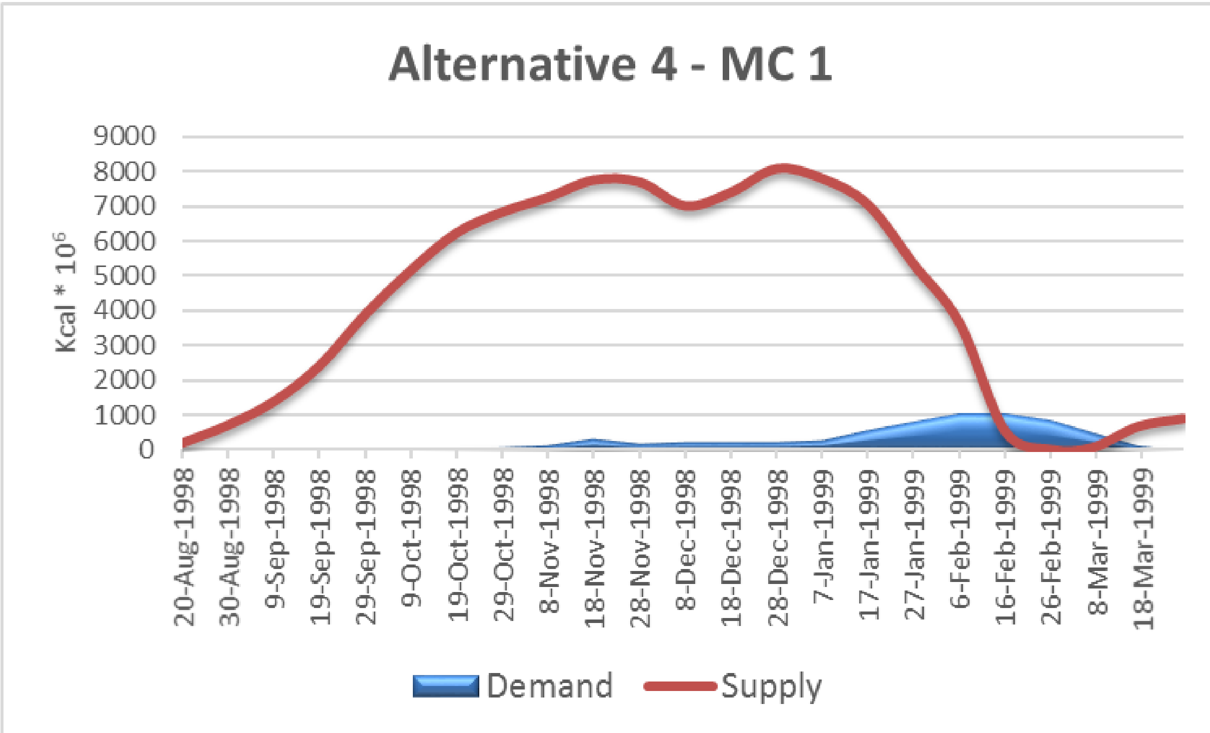


Figure 16. Duck food energy supply and demand curves: 1999 Alternative 4, MC 1 (Late-winter Peak).

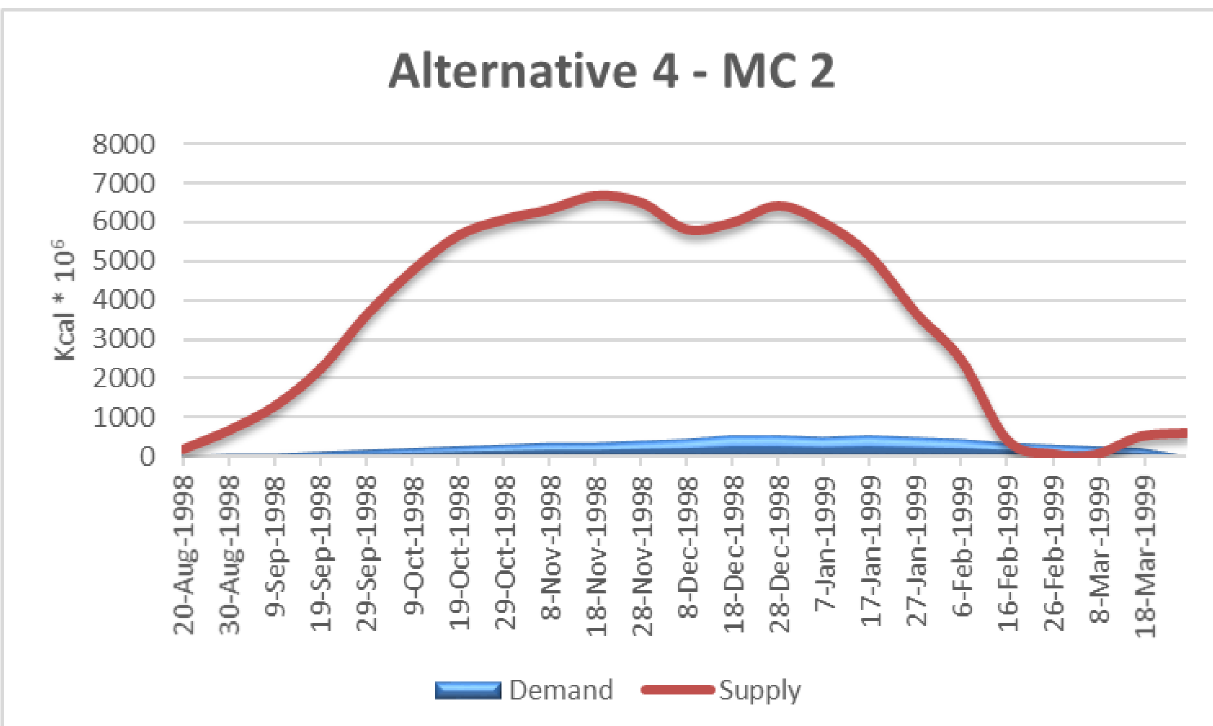


Figure 17. Duck food energy supply and demand curves: 1999 Alternative 4, MC 2 (Mid-winter Peak).

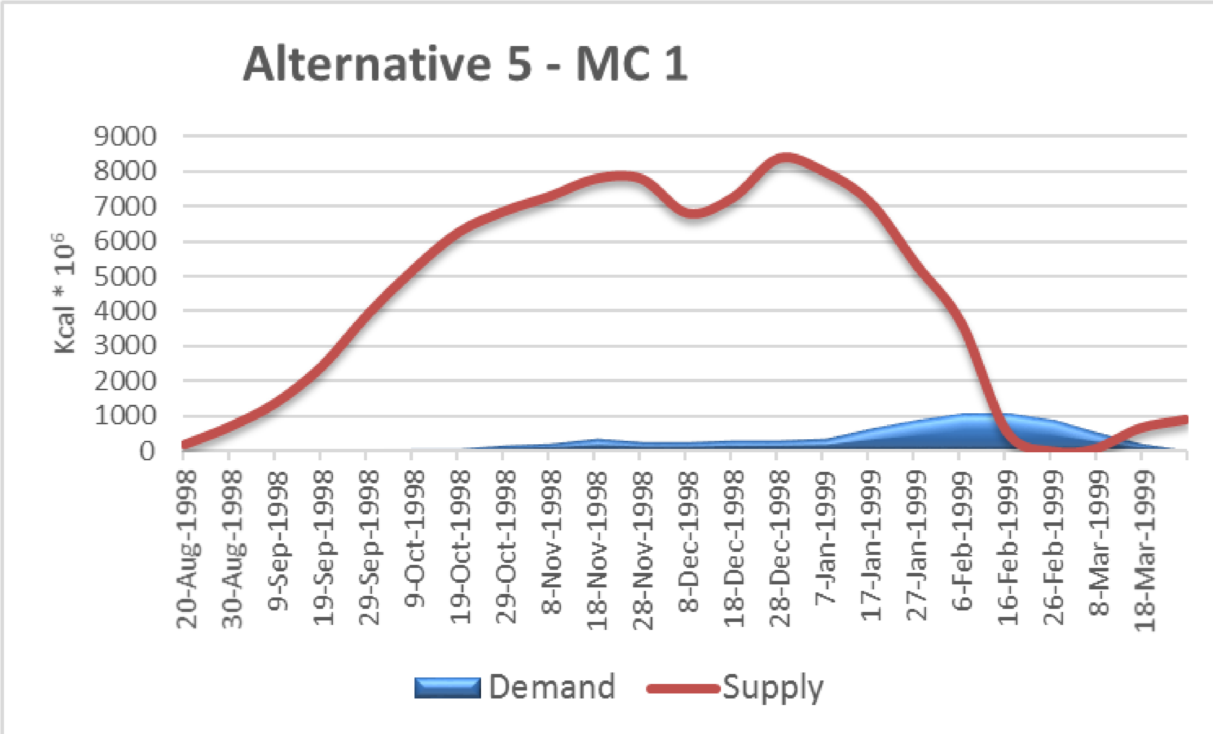


Figure 18. Duck food energy supply and demand curves: 1999 Alternative 5, MC 1 (Late-winter Peak).

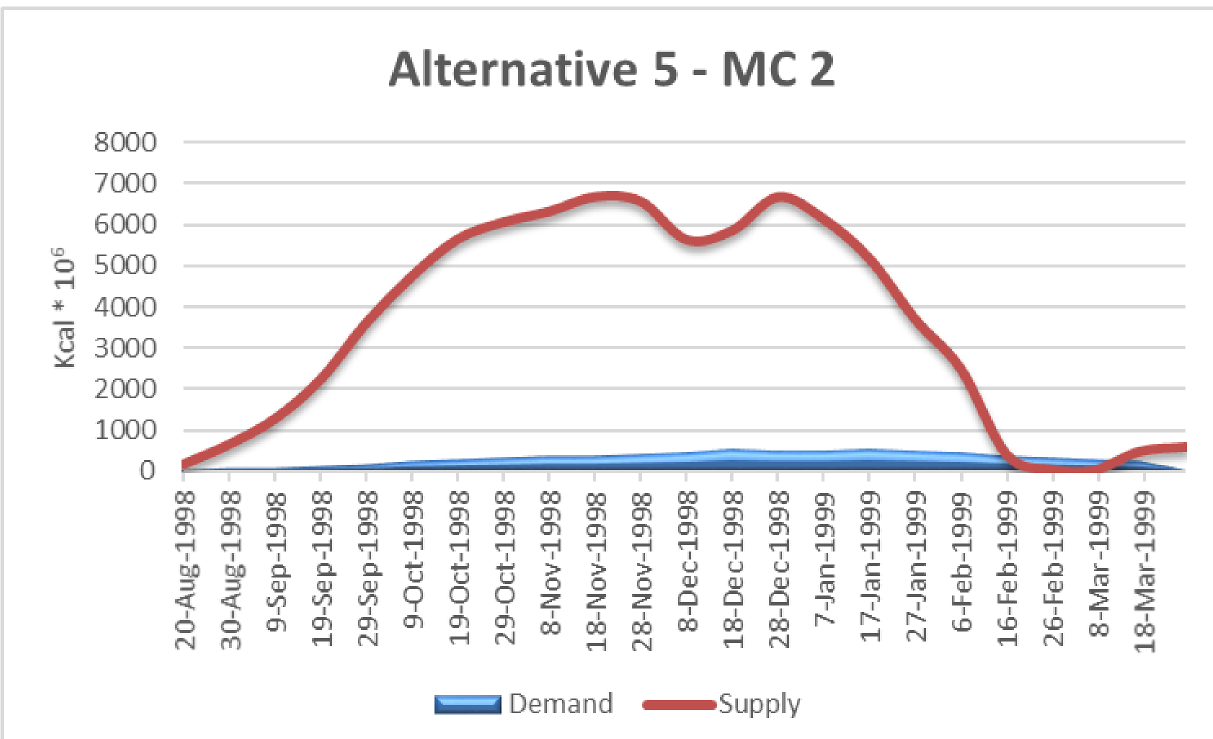


Figure 19. Duck food energy supply and demand curves: 1999 Alternative 5, MC 2 (Mid-winter Peak).

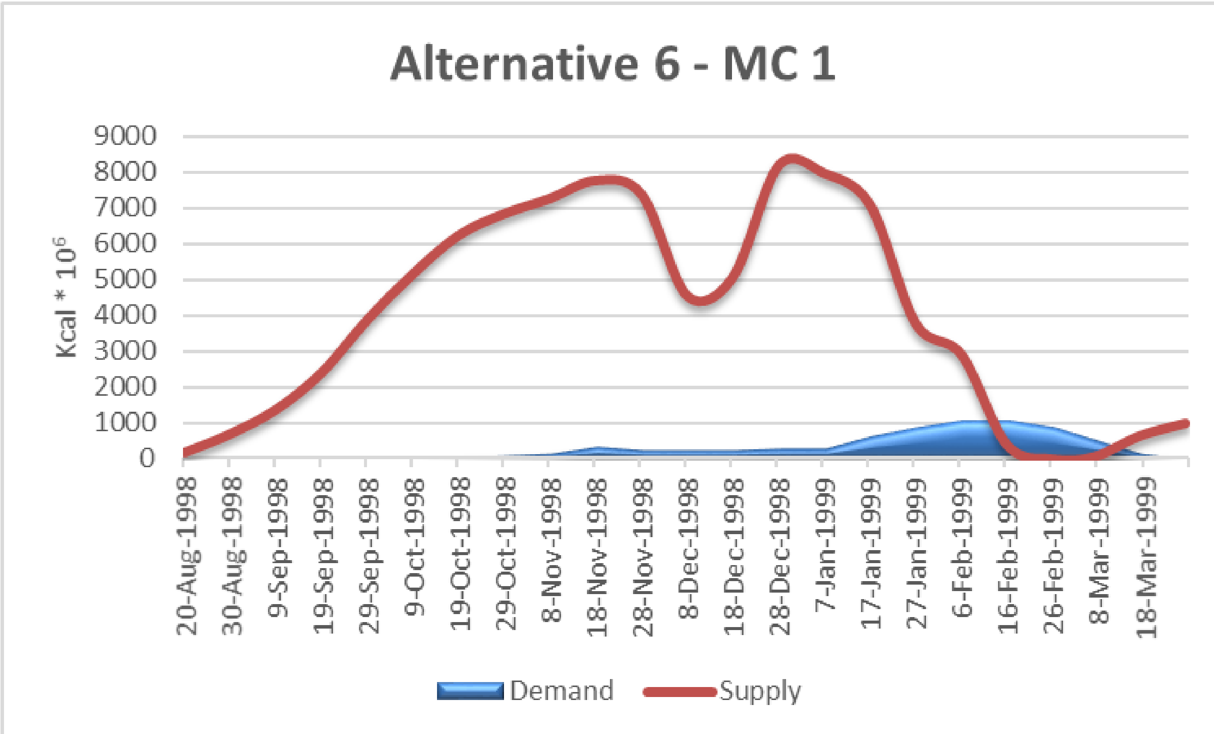


Figure 20. Duck food energy supply and demand curves: 1999 Alternative 6, MC 1 (Late-winter Peak).

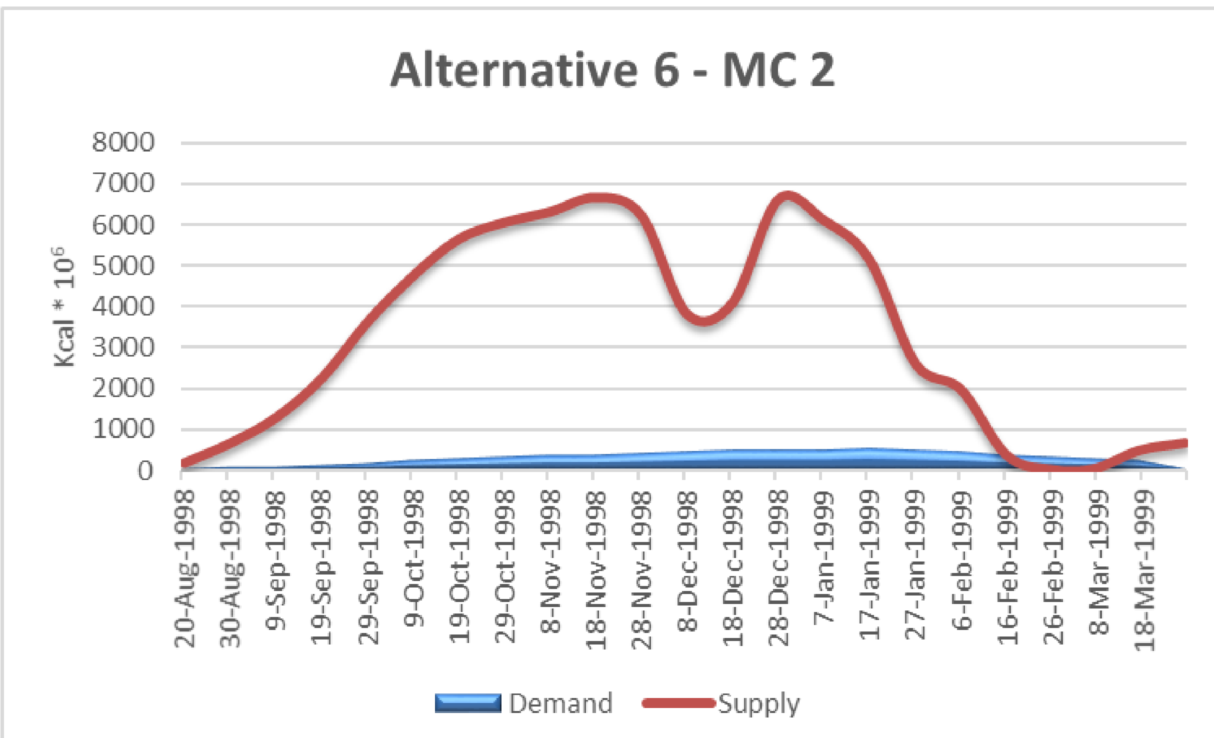


Figure 21. Duck food energy supply and demand curves: 1999 Alternative 6, MC 2 (Mid-winter Peak).

2002 Existing Conditions and Alternatives

For Existing Conditions, duck food energy supplies were insufficient to meet population energy demands by early March (Figure 22), similar to the food deficit documented for the Current Conditions scenario (Figure 10). In general, there was little difference in the supply-demand relationship between Existing Conditions and any of the four alternatives. Each scenario produced a similarly sharp decline in the supply curve from late December through mid-January before increasing in late January, though supply continued to remain above demand even during this period of decline (Figures22 - 26).

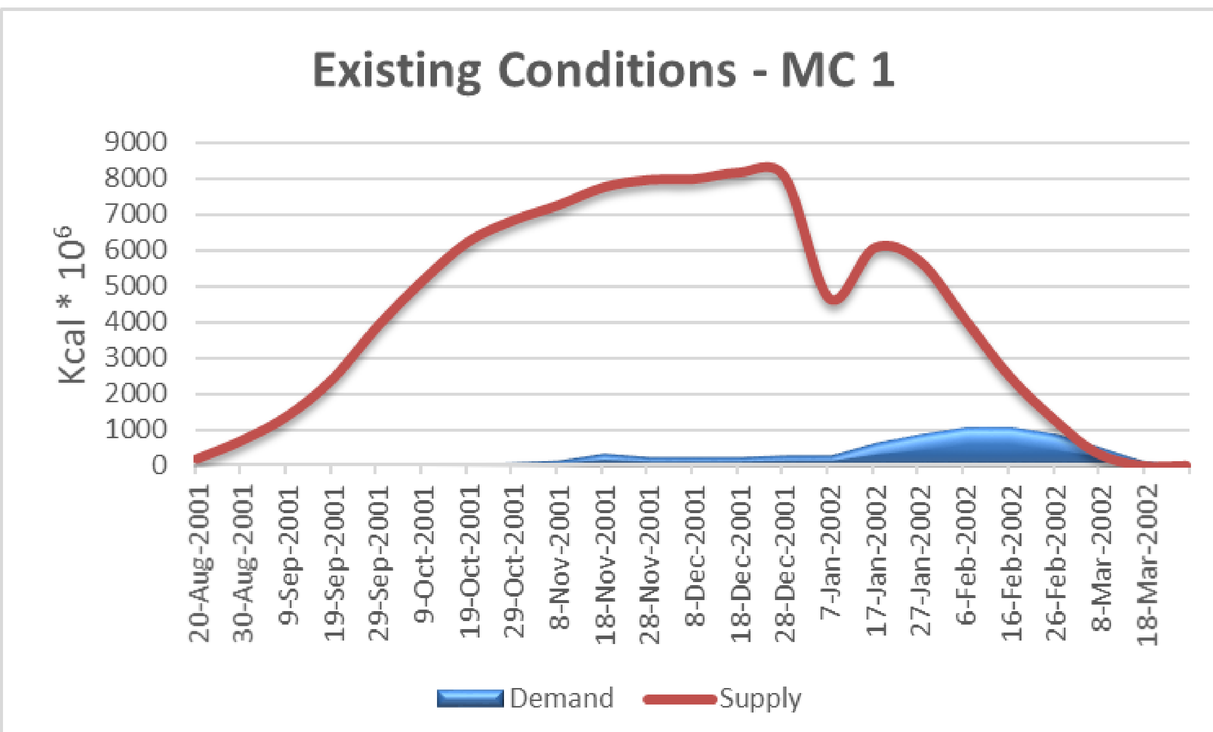


Figure 22. Duck food energy supply and demand curves: 2002 Existing Conditions, MC 1 (Late-winter Peak).

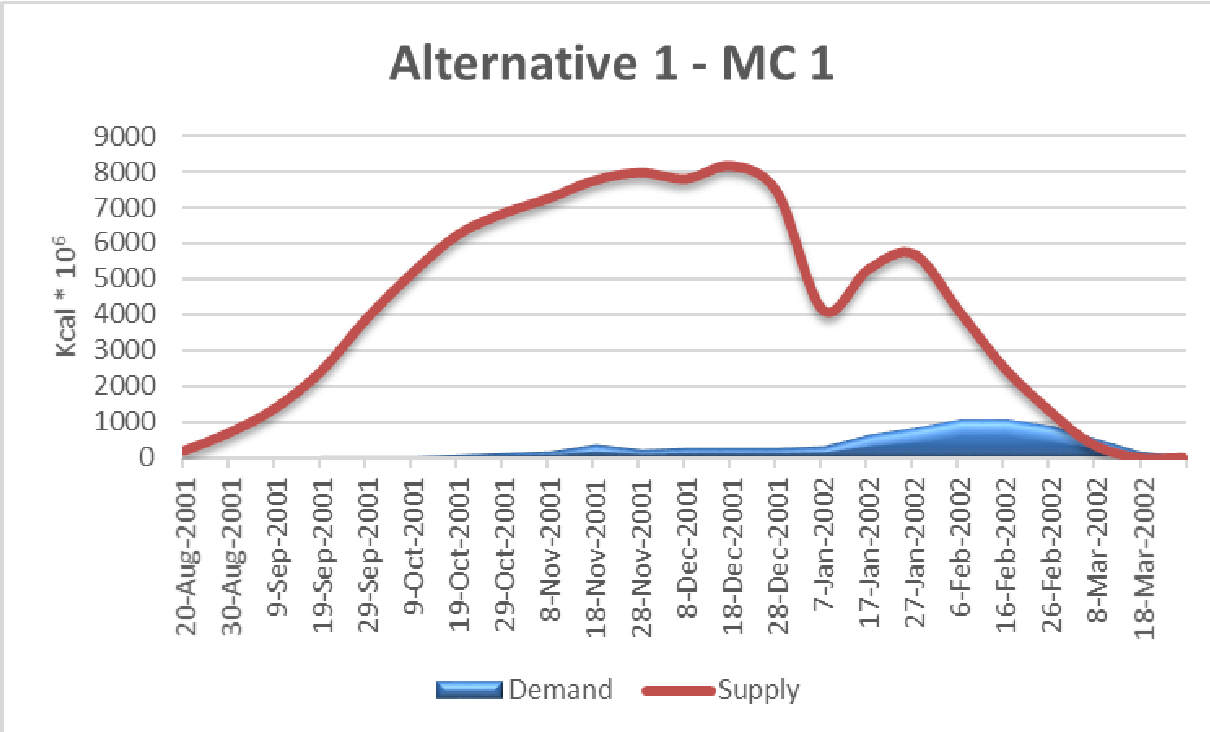


Figure 23. Duck food energy supply and demand curves: 2002 Alternative 1, MC 1 (Late-winter Peak).

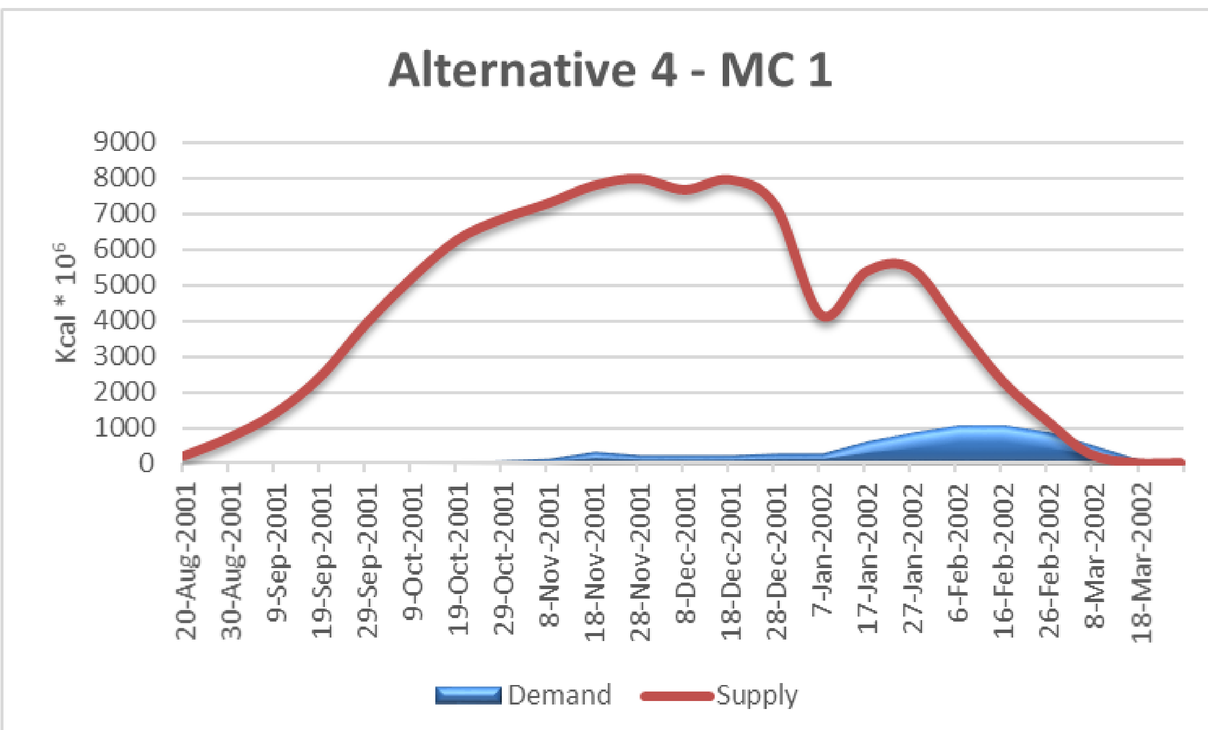


Figure 24. Duck food energy supply and demand curves: 2002 Alternative 4, MC 1 (Late-winter Peak).

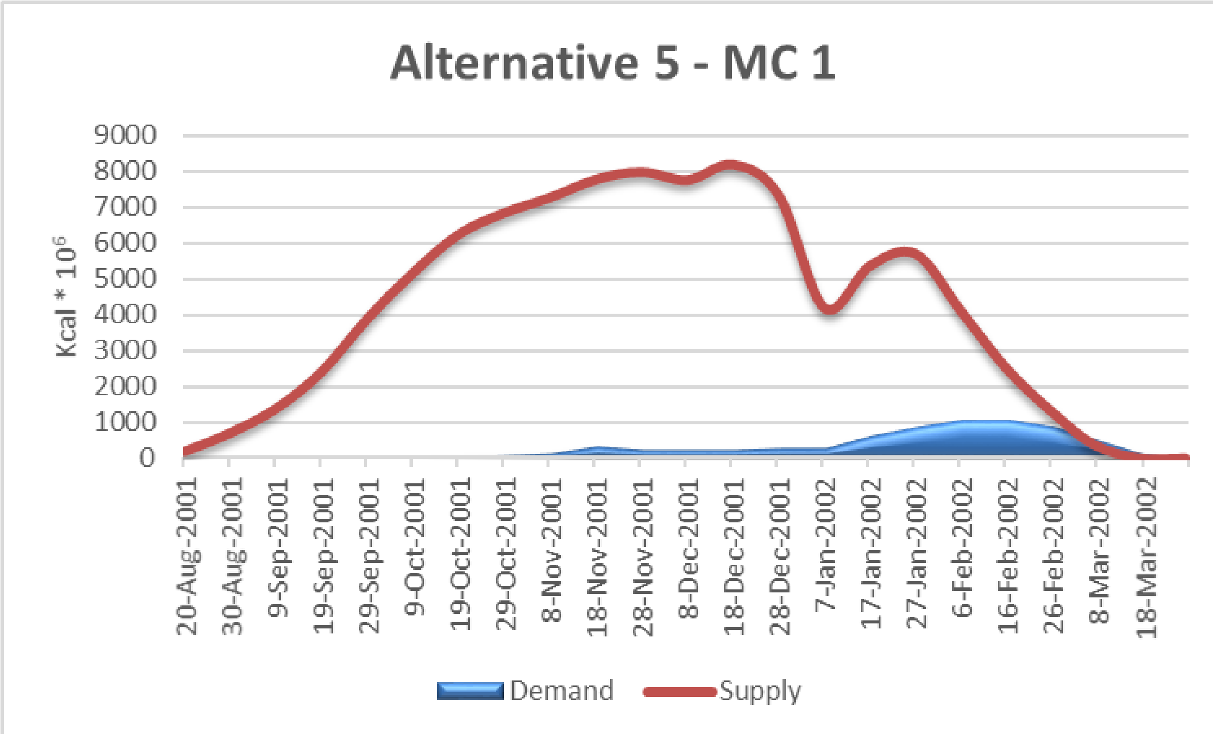


Figure 25. Duck food energy supply and demand curves: 2002 Alternative 5, MC 2 (Late-winter Peak).

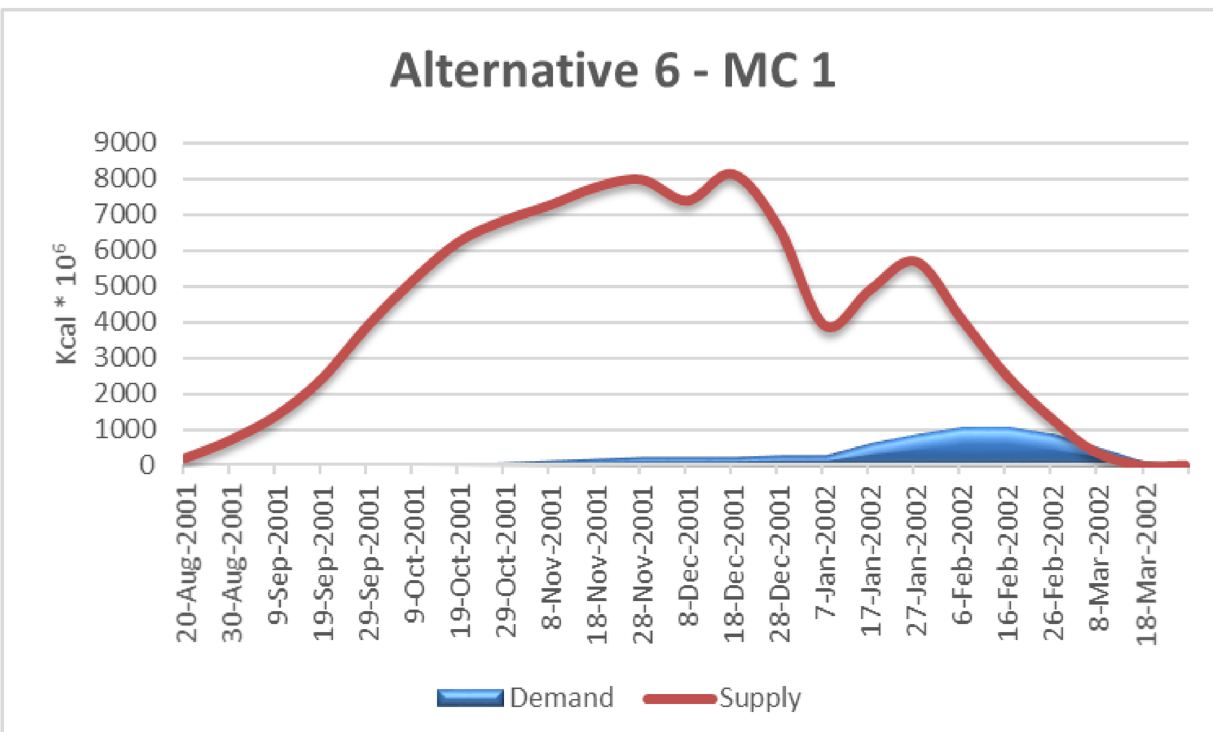


Figure 26. Duck food energy supply and demand curves: 2002 Alternative 6, MC 1 (Late-winter Peak).

2005 Existing Conditions and Alternatives

For Existing Conditions, duck food energy supplies were insufficient to meet population energy demands by early March (Figure 27), similar to the food deficit documented for the Current Conditions scenario (Figure 10). In general, the relationship between supply and demand was similar between Existing Conditions and each of the four alternatives, though the decline in from late December through mid-January was modestly higher for the alternatives (Figures 27 – 31).

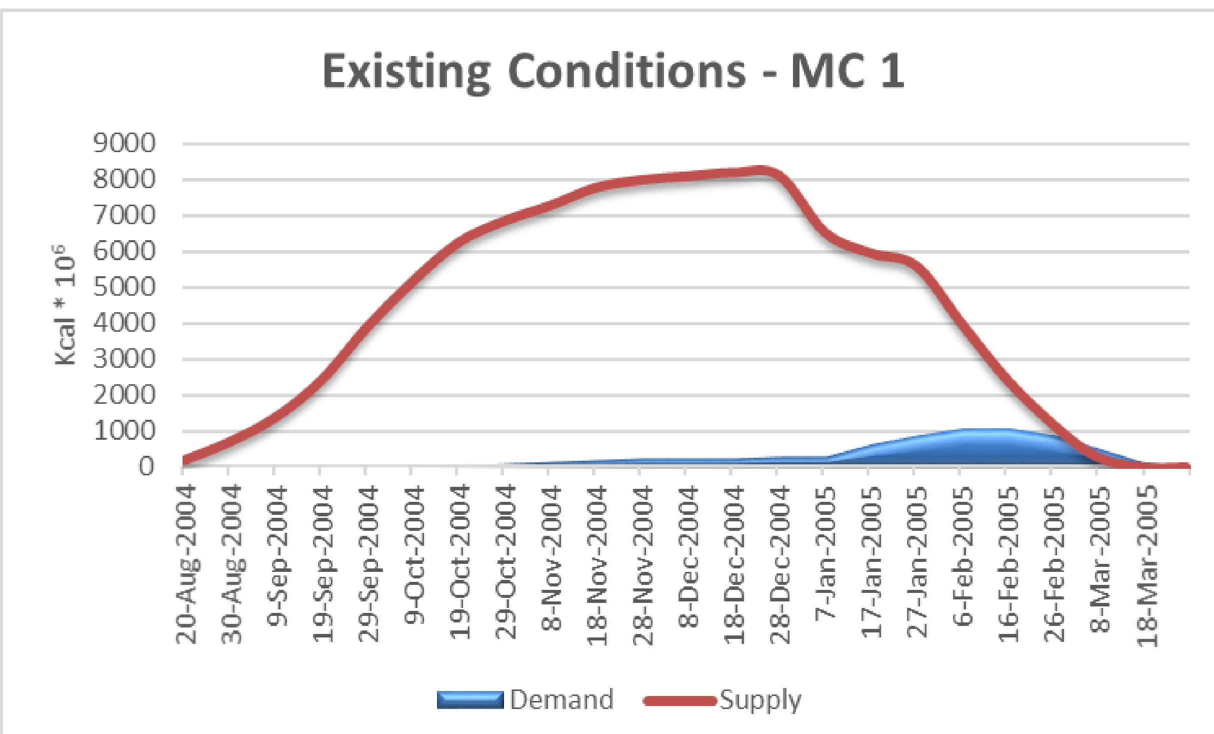


Figure 27. Duck food energy supply and demand curves: 2005 Existing Conditions, MC 1 (Late-winter Peak).

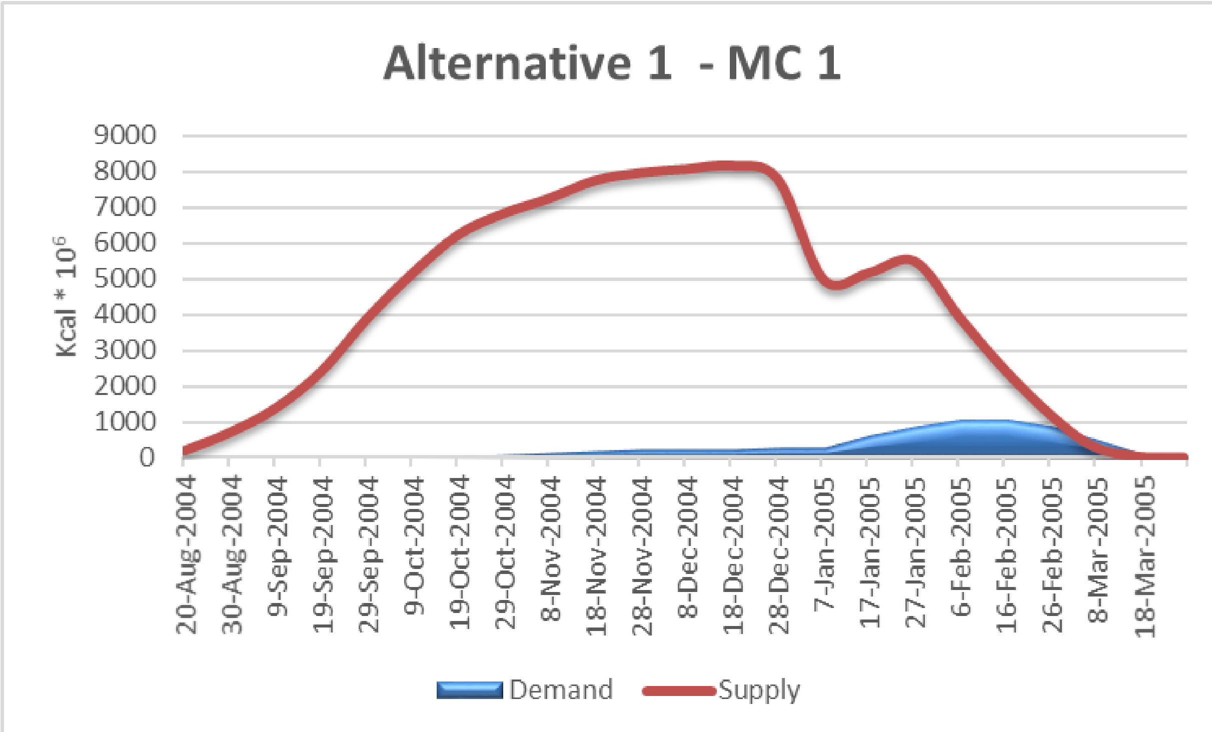


Figure 28. Duck food energy supply and demand curves: 2005 Alternative 1, MC 1 (Late-winter Peak).

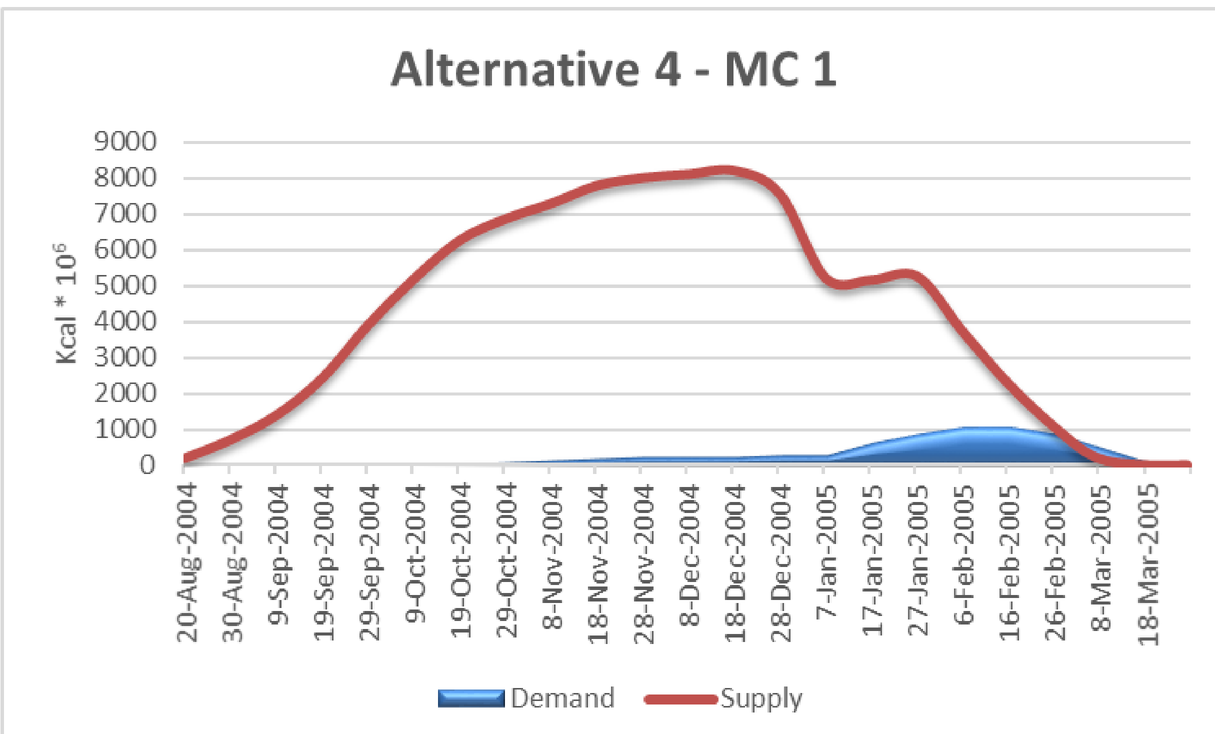


Figure 29. Duck food energy supply and demand curves: 2005 Alternative 4, MC 1 (Late-winter Peak).

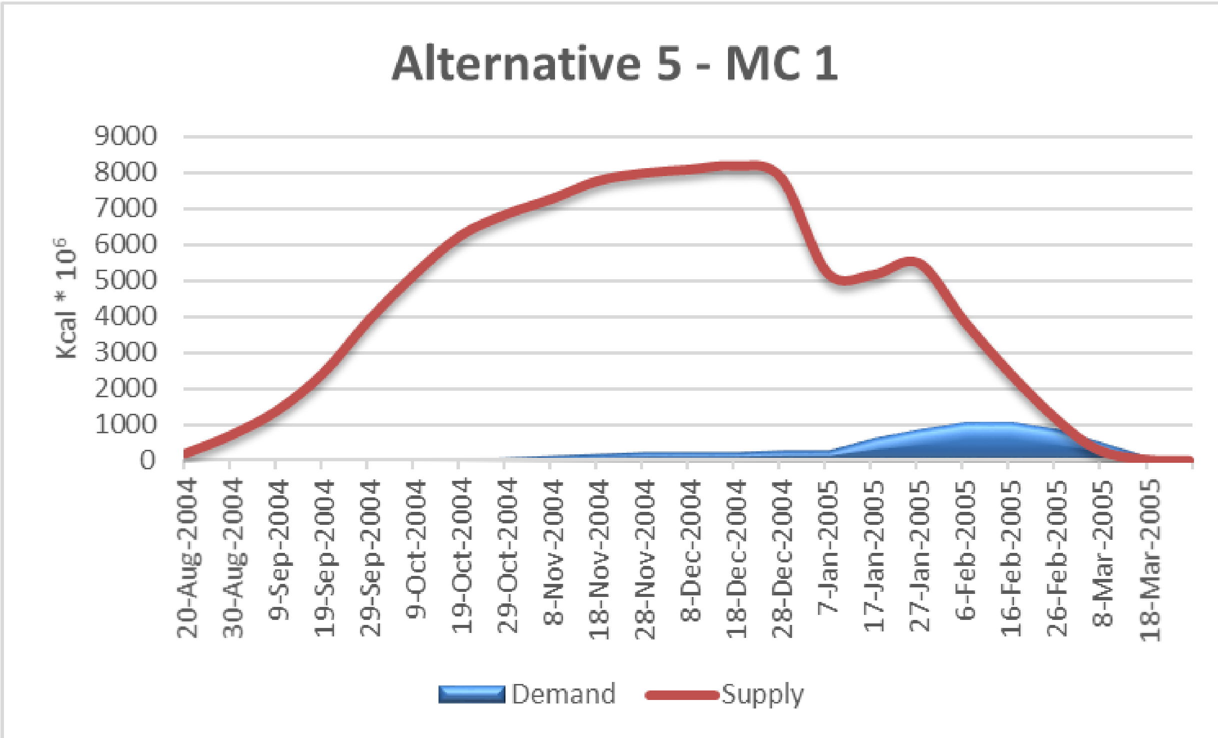


Figure 30. Duck food energy supply and demand curves: 2005 Alternative 5, MC 2 (Late-winter Peak).

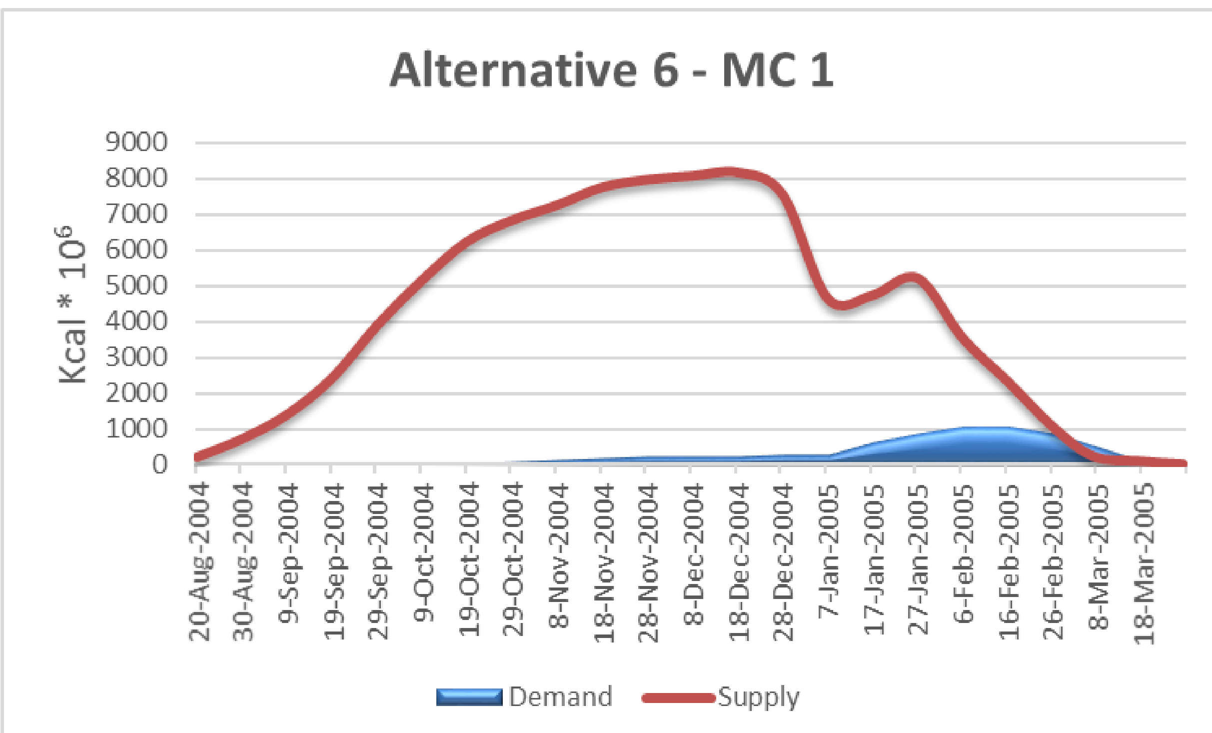


Figure 31. Duck food energy supply and demand curves: 2005 Alternative 6, MC 1 (Late-winter Peak).

Availability of Managed Seasonal Wetlands 1999

The acreage of available managed seasonal wetlands (i.e. flooded to a depth of ≤ 18 inches) under Existing Conditions was similar to that of Current Conditions through late December, where Current conditions reflect the CVJV's existing assumptions about wetland availability in the Yolo Basin. However, beginning in mid- January the availability of managed wetlands under Existing Conditions substantially declined relative to Current Conditions (Figure 7). **The availability of managed wetlands under Alternatives 6 and 1 was substantially less than for Existing Conditions during late November and early December (up to 7,000 and 4,500 acres respectively), while the availability of managed wetlands under Alternatives 4 and 5 also declined during this period relative to Existing Conditions (up to 2,500 and 1,500 respectively)**. Wetland availability for each Alternative was also less than for Existing Conditions for much of January; however, wetland availability was nearly identical for Existing Conditions and each Alternative after this period (Figure 7).

Availability of Managed Seasonal Wetlands 2002

The acreage of available managed seasonal wetlands under Existing Conditions was similar to that for Current Conditions through mid-November. Although wetland availability declined substantially from early December through early January, there was little difference among Existing Conditions and each Alternative during this period of decline. After mid-January the availability of managed seasonal wetlands under Existing Conditions and each Alternative equaled that of Current Conditions (Figure 8).

Availability of Managed Seasonal Wetlands 2005

The acreage of available managed seasonal wetlands under Existing Conditions was similar to that for Current Conditions through mid-December. Wetland availability under Existing Conditions declined relative to Current Conditions between mid-December and mid-January, but was similar to Current Conditions after mid-January. **The decline in wetland availability during the mid-December to mid-January period was significantly larger for most Alternatives compared to Existing Conditions by up to 5,000 acres.**

6 Discussion

It is important to distinguish between our use of "Current Conditions" and "Existing Conditions" as a baseline condition for evaluating the Fremont Weir management alternatives and the resulting impact on waterfowl habitat conditions in the Yolo Bypass and ultimately the Yolo Basin. Current Conditions reflect the CVJV's existing assumptions about habitat availability in the Yolo Basin, which do not account for the "natural" periodic flooding of the Yolo Bypass that makes some of these habitats unavailable because they are flooded to depths ≥ 18 inches. In contrast, Existing Conditions do account for these periodic flood events that "naturally" make some of these waterfowl foraging habitats unavailable because they are too deeply inundated. As a result Current Conditions provide a baseline from which to evaluate how flooding, regardless of its depth and duration, is likely to alter habitat availability from its ideal state as envisioned by the CVJV (i.e. where habitats are flooded over traditional time periods and water depths do not exceed 18 inches at any time for key habitat types). In contrast Existing Conditions reflect the fact that periodic "natural" flooding events do occur, and that these flood events make some habitats unavailable to waterfowl in a way independent of any decision on how the Fremont Weir is currently operated. As a result, alternative scenarios that do reflect how the Fremont Weir may be actively managed in the future should be judged against these Existing Conditions in terms of their waterfowl impacts.

The CVJV's current assumptions (i.e. Current Conditions) about waterfowl habitat in the Yolo Basin suggest that duck energy demand exceeds supply by early March when duck migration chronology corresponds to MC 1. In contrast, food energy supply remains above demand under current conditions when duck migration chronology for the Yolo Basin is similar to that of the Central Valley as a whole, as represented in MC 2. These differences are largely explained by the effects of food decomposition. Under MC 1, most population energy demand occurs in late winter – early spring after waterfowl food resources have been subject to considerable decomposition as a result of being flooded for several months. These partially decomposed food resources are less able to meet population energy demand compared to MC 2 where there has been less time for these food sources to deteriorate.

Although we explored the possible effects of using different migration chronologies in our 1999 simulations, there was little evidence that the choice of migration chronology impacted our overall conclusions. Thus our discussion of the 1999 results focuses on those model simulations that used MC 1, which is the migration chronology now assumed by the CVJV. Although Existing Conditions in 1999 drove supply below demand approximately two weeks earlier than Current Conditions during the late winter - early spring period, there was little difference in 1999 between Existing Conditions and each of the alternatives in terms of when duck food sources were completely depleted in the late winter – early spring period. In contrast some of the alternatives in 1999 differed substantially from existing conditions in terms of duck food energy supplies during late November through late December, though in no case did demand exceed supply.

Although none of the 1999 alternatives drove food energy supply below demand in the late November-late December period, the substantial decline in the supply curve for some alternatives during this period (e.g. Alternatives 1and 6) warrants further consideration. In theory, duck use of the Yolo Basin / Bypass should be unaltered during this decline in food energy supply as food supplies remain above population energy needs. However, the possible effects of these alternatives on duck use of the Yolo Basin needs to be considered in the larger context of the Central Valley landscape. The food supplies available to ducks in the Central Valley generally increase in an almost linear fashion from late August through mid-December as foraging habitats like managed seasonal wetlands and harvested rice fields are intentionally flooded (CVJV 2006). Reversing the supply curve for ducks in the Yolo Basin during a period of time when habitat conditions are improving in surrounding landscapes (i.e. in other drainage basins) may discourage bird use of the Yolo Basin regardless of the predicted relationship between supply and demand.

Any alternative effects on the supply curve, even when supply is not driven below demand, needs to be also considered relative to hunting opportunities and the long-term incentive to invest in the management of seasonal wetlands, especially on private lands. The late November-late December drop in the supply curve for the 1999 alternatives compared to Existing Conditions is mirrored by a similar decline in the availability of managed seasonal wetlands that are ≤ 18 inches in depth. This is to be expected as managed wetlands account for nearly 70% of all duck food resources in the Yolo Basin. A similar relationship between declines in the supply curve and the availability of managed wetlands is also apparent for the 2002 and 2005 results.

Most of the hunting opportunity in the Yolo Basin is likely provided by managed seasonal wetlands. Moreover, approximately two thirds of these wetlands are privately owned and managed as duck clubs. Alternatives that increase deep flooding of these managed wetlands compared to Existing Conditions will further reduce hunting opportunities on these wetlands regardless of any relationship between duck population energy demand and food energy supply. Moreover, alternatives that reverse the supply curve as described earlier may further reduce hunting opportunities by discouraging bird use in the Yolo Basin. Perhaps most importantly, alternatives that discourage private duck clubs from continuing to invest in wetland management because of declining hunting opportunities may, in the long term, seriously erode the waterfowl carrying capacity of the Yolo Basin.

7 References

Central Valley Joint Venture, 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Fleskes, J.P., Yee, J.L., Casazza, M.L., Miller, M.R., Takekawa, J.Y., Orthmeyer, D.L., 2005. Waterfowl distribution movements and habitat use relative to recent changes in the Central Valley of California. Final report U.S. Geological Survey Western Ecological Research Center, Dixon Field Station, Dixon, California.

Fredrickson, L., Taylor, S.T., 1982. Management of Seasonally Flooded Impoundments for Wildlife. U.S. Department of the Interior, Fish and Wildlife Service Resource Publication 148.

Garg, J.M., 2007. Northern Pintails – Upending, Wikimedia Commons GNU Free Documentation License. http://en.wikipedia.org/wiki/File:Northern_Pintails_%28Male_%26_Female%29-_Up-ending_I_342.jpg (accessed February, 25, 2002)

Miller, M.R., Newton, W.E., 1999. Population energetics of northern pintails in the Sacramento Valley. Journal of Wildlife Management 63:1222-1238.

Miller, M.R., Eadie, J.M., 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. Condor 108:166–177.

Naylor, L.W., 1999, Evaluating moist-soil production and management in Central Valley wetlands to determine habitat needs for waterfowl. MS thesis, University of California, Davis, CA.

Nelson, F., 2012. Shallow Water Management for Dabbling Waterfowl: Fish and Wildlife Habitat Management Guidesheet. Natural Resource Conservation Service MN, U.S. Department of Agriculture with content provided by the Missouri Department of Conservation.

Williams, C.K., Dugger, B.D., Brasher, M.G., Coluccy, J.M., Cramer, D.M., Eadie, J.M., Gray, M.J., Hagy, H.M., Livolsi, M., McWilliams, S.R., Petrie, M., Soulliere, G.J., Tirpak, J.M., Webb, E.B., 2014. Estimating habitat carrying capacity for migrating and wintering waterfowl: considerations, pitfalls and improvements. Wildfowl special issue 4: 407-435.

Appendix A. GIS BDepth Model Output Summary Tables and Graphs

Water Year 1999 (Wet Year)													
		Additional Acre-Days of Flooding for Five Alternatives Compared with Existing Conditions											
		Managed Seasonal Wetlands			Rice Fields			Upland / Other			Other Agriculture		
	Alternative	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")
Total Additional Acre-Days	Alternative 1	-	93,473	145,148	-	73,844	95,905	-	31,754	61,650	-	46,474	95,953
	Alternative 4	-	84,150	41,388	-	90,183	132,935	-	23,222	34,681	-	65,159	118,274
	Alternative 4 March 7	-	84,541	40,166	-	90,436	131,935	-	22,672	31,847	-	65,636	117,260
	Alternative 5	-	98,162	71,926	-	86,614	59,898	-	33,110	52,681	-	52,050	69,149
	Alternative 6	-	89,934	247,590	-	81,671	144,752	-	70,110	120,723	-	42,545	141,367
Average # Acres / Day	Alternative 1	-	386	600	-	305	396	-	131	255	-	192	397
	Alternative 4	-	348	171	-	373	549	-	96	143	-	269	489
	Alternative 4 March 7	-	349	166	-	374	545	-	94	132	-	271	485
	Alternative 5	-	406	297	-	358	248	-	137	218	-	215	286
	Alternative 6	-	372	1,023	-	337	598	-	290	499	-	176	584

* Average # Acres/Day is calculated as: "Total Additional Acre-Days"/242. Water year data ranged from October 2, 1998 - May 31, 1999 (242 days).

Appendix A – Table 1. Number of additional "acre-days" of flooding for five management alternatives when compared to existing conditions, for water year 1999.

		Water Year 2002 (Dry year)											
		Additional Acre-Days of Flooding for Five Alternatives Compared with Existing Conditions											
		Managed Seasonal Wetlands			Rice Fields			Upland / Other			Other Agriculture		
	Alternative	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")
Total Additional Acre-Days	Alternative 1	-	16,439	47,252	-	24,971	28,206	-	10,715	27,969	-	6,739	31,173
	Alternative 4	-	20,129	40,803	-	81,733	152,534	-	12,759	36,184	-	55,659	143,202
	Alternative 4 March 7	-	20,094	40,727	-	73,560	140,725	-	12,231	33,433	-	49,683	131,641
	Alternative 5	-	22,832	47,477	-	30,794	28,665	-	14,426	35,373	-	10,228	32,360
	Alternative 6	-	45,458	87,258	-	45,512	57,425	-	20,427	55,832	-	20,505	57,814
Average # Acres / Day*	Alternative 1	-	68	195	-	103	117	-	44	116	-	28	129
	Alternative 4	-	83	169	-	338	630	-	53	150	-	230	592
	Alternative 4 March 7	-	83	168	-	304	582	-	51	138	-	205	544
	Alternative 5	-	94	196	-	127	118	-	60	146	-	42	134
	Alternative 6	-	188	361	-	188	237	-	84	231	-	85	239

* Average # Acres/Day is calculated as: "Total Additional Acre-Days"/242. Water year data ranged from October 2, 1998 - May 31, 1999 (242 days).

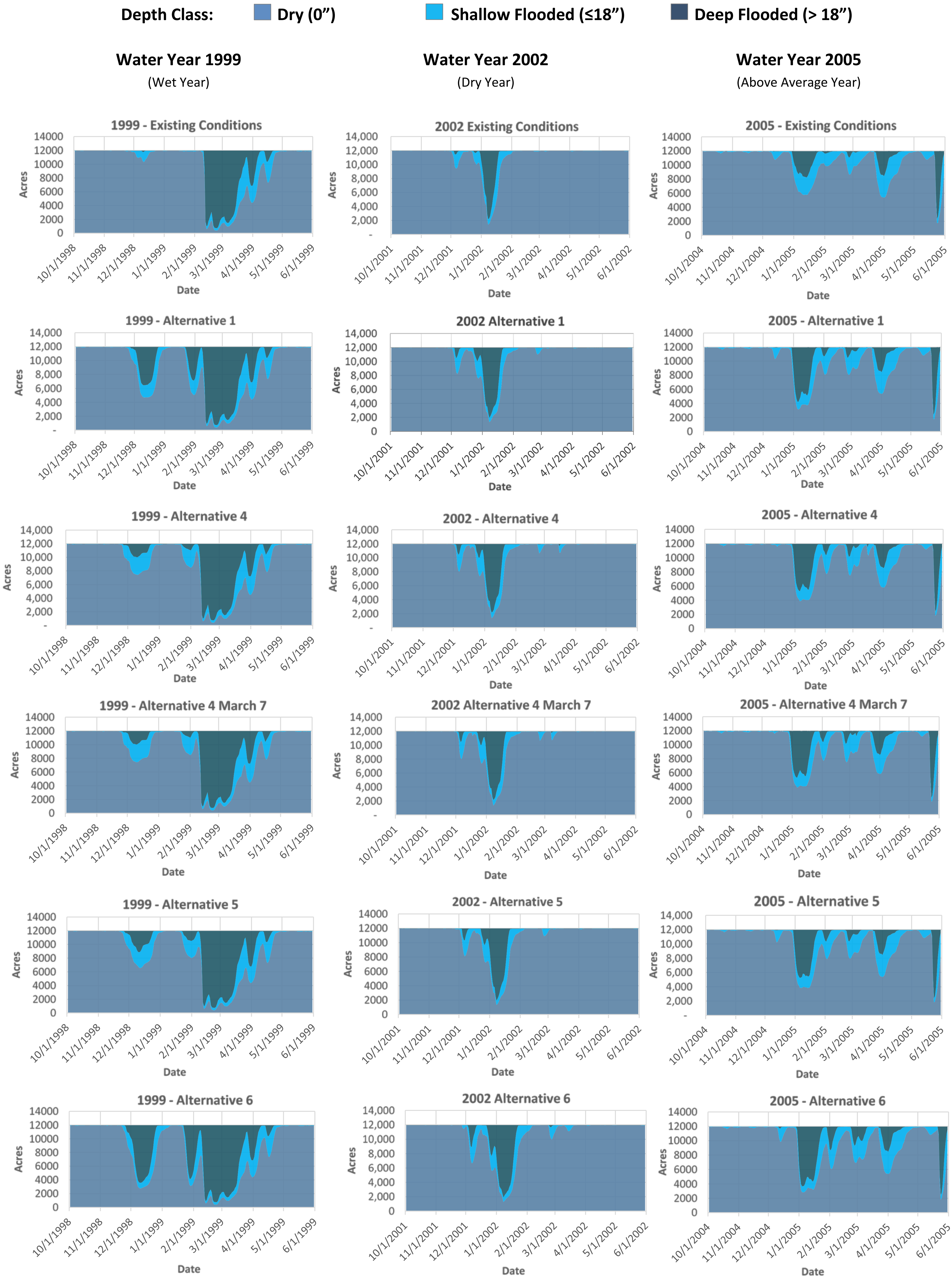
Appendix A - Table 2. Number of additional "acre-days" of flooding for five management alternatives when compared to existing conditions, for water year 2002.

	Water Year 2005 (Above Normal Year)												
		Additional Acre-Days of Flooding for Five Alternatives Compared with Existing Conditions											
		Managed Seasonal Wetlands			Rice Fields			Upland / Other			Other Agriculture		
	Alternative	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Managed (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")	Not Flooded (0")	Shallow Flooded (<18")	Deep Flooded (>18")
Total Additional Acre-Days	Alternative 1	-	(2,468)	72,929	-	(2,234)	32,600	-	13,702	29,568	-	(5,204)	33,653
	Alternative 4	-	(23,335)	66,060	-	19,409	156,930	-	11,675	36,272	-	15,397	132,168
	Alternative 4 March 7	-	(22,909)	66,319	-	15,846	145,906	-	11,686	34,172	-	11,432	121,597
	Alternative 5	-	5,667	70,258	-	4,567	34,579	-	23,235	41,237	-	(1,803)	35,424
	Alternative 6	-	18,549	124,442	-	16,685	63,310	-	24,691	59,309	-	(884)	63,579
Average # Acres / Day*	Alternative 1	-	(10)	301	-	(9)	135	-	57	122	-	(22)	139
	Alternative 4	-	(96)	273	-	80	648	-	48	150	-	64	546
	Alternative 4 March 7	-	(95)	274	-	65	603	-	48	141	-	47	502
	Alternative 5	-	23	290	-	19	143	-	96	170	-	(7)	146
	Alternative 6	-	77	514	-	69	262	-	102	245	-	(4)	263

* Average # Acres/Day is calculated as: "Total Additional Acre-Days"/242. Water year data ranged from October 2, 1998 - May 31, 1999 (242 days).

Appendix A - Table 3. Number of additional “acre-days” of flooding for five management alternatives when compared to existing conditions, for water year 2005.

Acres of Seasonal Wetlands Flooded in the Yolo Bypass, by Depth Class, for 3 Water Years and 5 Management Alternatives

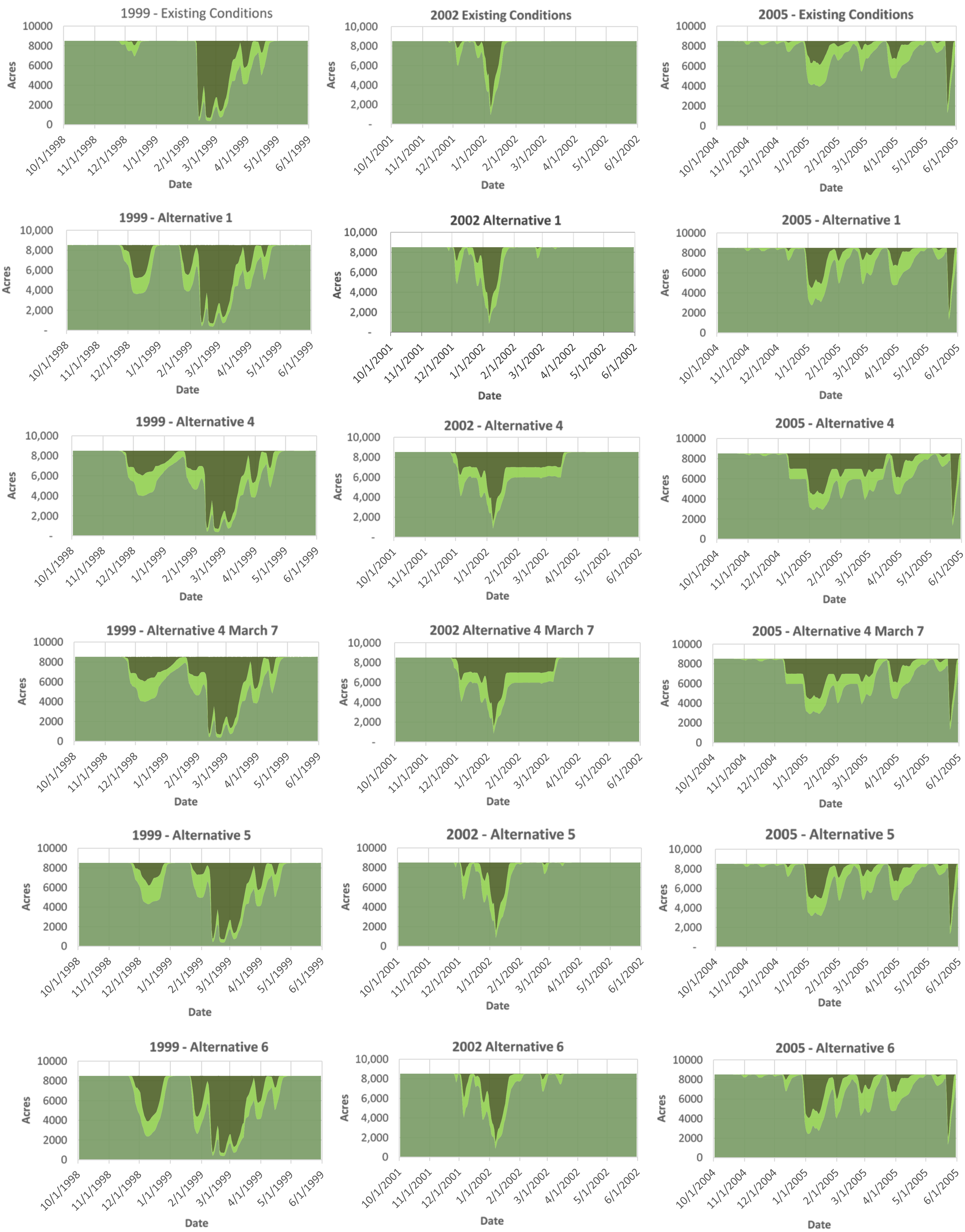


Appendix A – Figure 1. Acres of seasonal wetlands flooded in the Yolo Bypass, by Depth Class, for three water years and 5 management alternatives.

Acres of Rice Fields Flooded in the Yolo Bypass, by Depth Class, for 3 Water Years and 5 Management Alternatives

Depth Class: Managed (0”) | Shallow Flooded (≤18”) | Deep Flooded (> 18”)

Water Year 1999	Water Year 2002	Water Year 2005
(Wet Year)	(Dry Year)	(Above Average Year)



Appendix A – Figure 2. Acres of rice agriculture flooded in the Yolo Bypass, by Depth Class, for three water years and 5 management alternatives.