Title
Initial Hydrologic Feasibility Analysis of the Proposed Ship Channel Bypass (lower Sacramento River, California

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Initial Hydrologic Feasibility Analysis of the Proposed Ship Channel Bypass *(lower Sacramento River, California)*

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ABSTRACT. A new bypass channel, similar to the Yolo Bypass, is being proposed for the lower Sacramento River. However, flood conditions on the mainstem Sacramento River have not been analyzed to determine the likelihood of inundation of the proposed Ship Channel Bypass. This project 1) assesses flow conditions on the mainstem Sacramento River to determine if and when the proposed bypass could be inundated under the current flow regime, and 2) uses four flow scenarios to estimate the number of days the Ship Channel Bypass could be inundated in a dry, wet, and normal year.

INTRODUCTION

The City of Sacramento's location at the confluence of two major rivers in northern California (the Sacramento and American rivers) puts it at great risk of flooding each year. Since 1911, Sacramento has been protected by the Yolo Bypass (FIGURE 1). The Yolo Bypass is the largest flood control bypass in California, having been designed to convey the 100-year flood, and the fact that the system has not failed despite several decades of operation suggests a high degree of success (Sommer et al. 2001a).

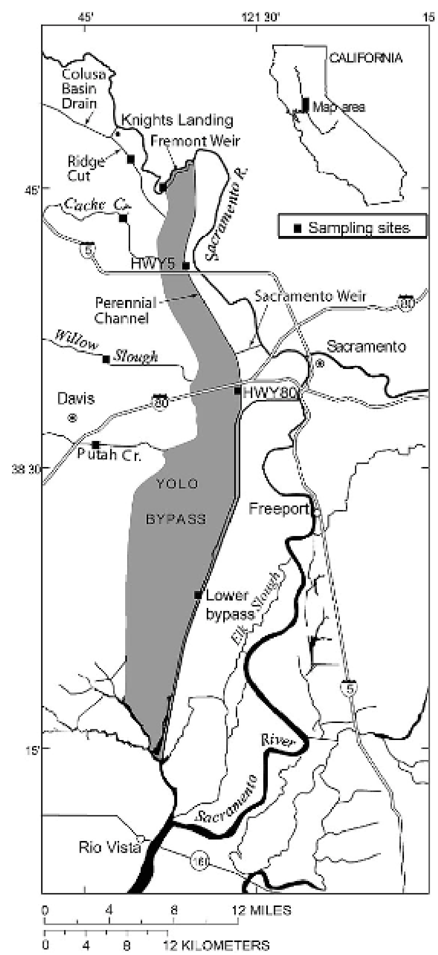

FIGURE 1: Location and extent of the Yolo Bypass near Sacramento (Schemel 2002).

The Yolo Bypass is an excellent example of how flood bypasses can serve the duel purposes of flood conveyance and important floodplain a habitat. The Yolo Bypass has extraordinary biological value for many native aquatic and terrestrial wildlife species (NHI et al. 2003). Excess floodwaters entering the bypass can create vast expanses of shallow water habitat for native fish and migratory and wintering shorebird populations, including highly productive habitat for several special-status fish species (CDFG 2008, Sommer et al. 2001b). Much of the historical floodplain in the Sacramento Valley has been lost to development, river channelization, flow alteration and levee construction. As such, the Yolo Bypass is now the largest contiguous floodplain of the lower Sacramento River. However, the need for the Yolo Bypass to retain its function of flood conveyance means that land use modification within the Bypass in the Yolo Bypass – even for beneficial ecological restoration, is restricted.

Despite the success of the Yolo Bypass, large tracts of urban areas remain at high risk of flooding. In particular, the “Pocket Area” of Sacramento is bordered by the Sacramento River on three sides and is protected by delta levees. It is a highly urbanized and densely populated area with a high risk of flooding. In the case of a levee breach, the 134,000 inhabitants could find themselves under 10 ft of water (FIGURE 2). This is one of the driving forces for expanding the capacity of the Bypass system.

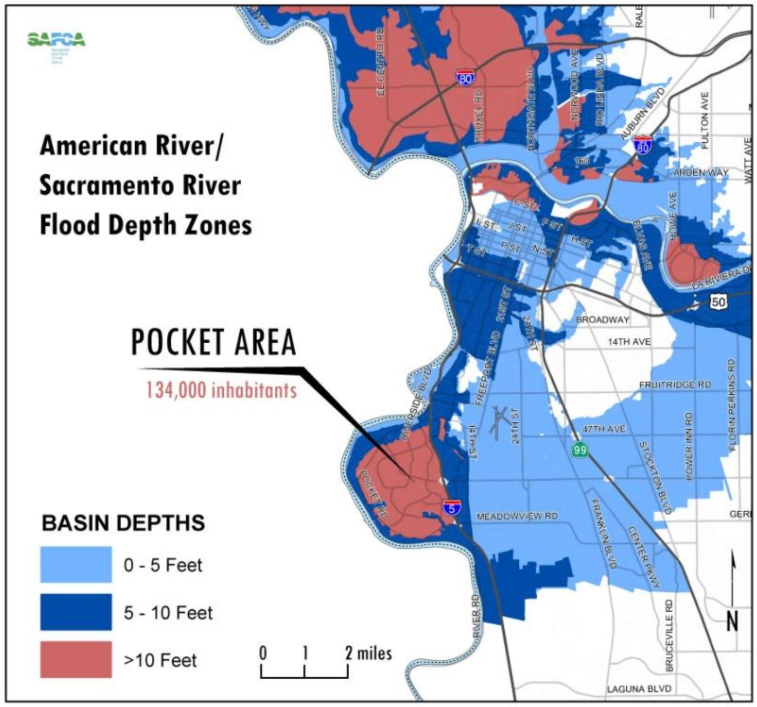

FIGURE 2: Flood depth zones at the confluence of the Sacramento and American rivers (Modified from SAFCA’s Flood Depth Zones map).

Much attention has been given to expanding and reconfiguring the operations of the Yolo Bypass; however, consideration has also been given to creating an entirely new bypass. Low-lying land east of the Yolo Bypass and west of the Sacramento River could be converted to a 25 kilometer (15 mile) flood bypass (termed the Ship Channel Bypass for its proximity to the Sacramento River Deep Water Ship Channel) (FIGURE 3). Flood waters from the Pocket Area would be diverted onto the proposed bypass, which would exit at Prospect Island. FIGURE 3 illustrates the two bypass configurations (Options A and B) currently under consideration. The proposed bypass could reduce flood risk by routing water away from urban Sacramento, reducing flood stage on the Sacramento River mainstem, thereby reducing flood risk in downstream areas, including the Pocket Area. In addition, the new bypass could be actively planted with riparian vegetation and provide up to 5,000 acres of inundated floodplain habitat (American Rivers 2010).

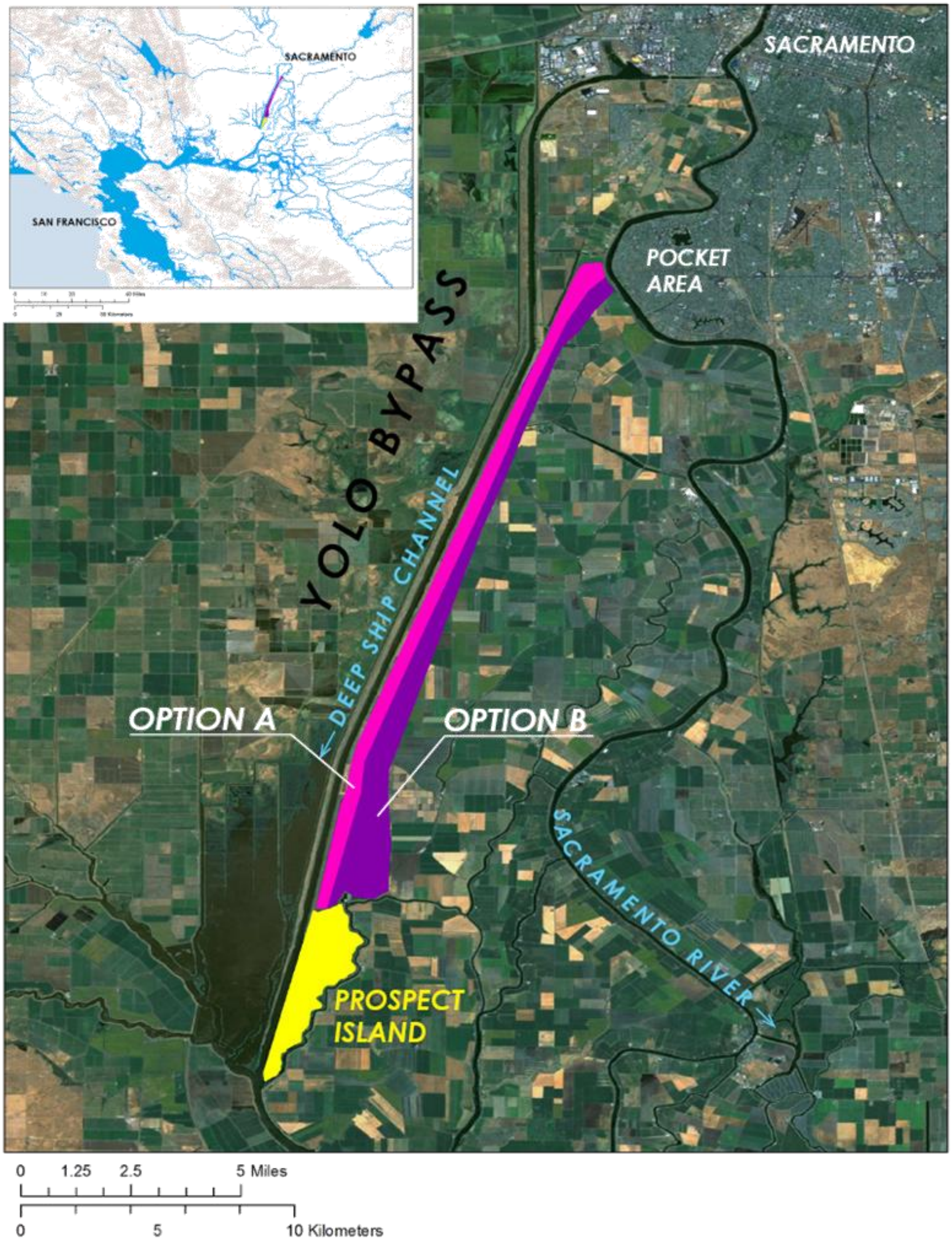

FIGURE 3: Location and extent of each of the proposed bypass configurations. Inset map shows the location of the bypass relative to the San Francisco Bay Area.

The Ship Channel Bypass would address two goals for the area: 1) decrease flood stage on the mainstem Sacramento River by attenuating floods on the Ship Channel Bypass, and 2) create riparian and wetland habitat that is inundated on a regular basis. Species and their habitat distribution are ultimately driven by physical factors (e.g., hydrology and topography) (FIGURE 4). As such it is necessary to structure the data acquisition and analysis in a step-wise process starting from the "ground" up to consider physical inputs.

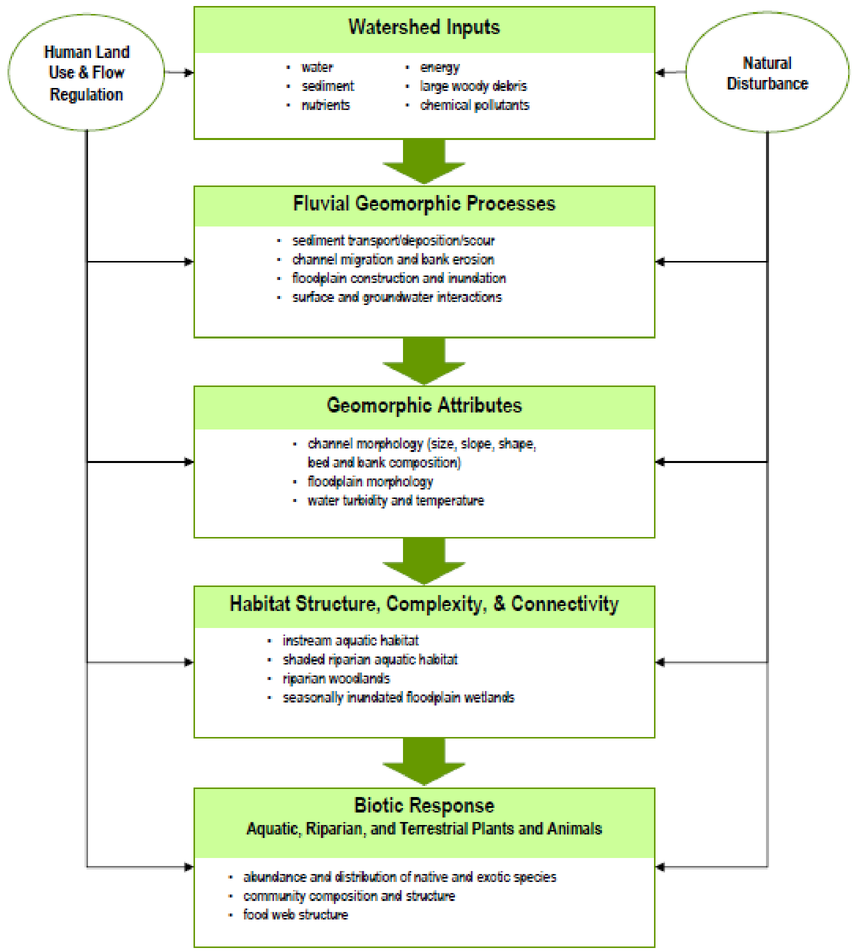

FIGURE 4: Conceptual understanding of linkages between watershed inputs, process, form, habitat and biota in alluvial river-floodplain systems (Stillwater Sciences 2005).

But before embarking on such an immense project, basic questions need to be answered to fully assess the potential of the Ship Channel Bypass. This report addresses the first step in for assessing the feasibility of the Ship Channel Bypass to provide inundated floodplain habitat for fish and other wetland species.

The timing of inundation has important implications for agricultural interests. Inundation in late-spring or early-fall can have dire consequences for unharvested or newly planted crops (CDFG 2008). While agriculture is one possible land use that could be supported in the Ship Channel Bypass, one of the potential benefits of the new bypass is that land use does not have to be as strictly managed as the Yolo Bypass and the Ship Channel Bypass could be actively planted for a wider range of vegetation types (including ecological restoration [e.g., riparian forest]). Whether for agriculture or ecological restoration, timing of inundation is an important consideration when evaluating the new Ship Channel

Bypass. Many riparian plants have life history requirements which rely on certain flood characteristics; also, the timing and duration of inundation will determine what habitats occur there and which species they benefit.

If ecological value were considered as part of the rationale for an additional bypass, the first thing to consider is the feasibility relative to the hydrology -- specifically the timing, frequency, and duration of flows required to inundate the bypass channel. Therefore, the intent of this study is to analyze existing hydrologic data and address the following key questions:

1. Are there excess flows that could be diverted onto the proposed bypass?
2. When do they occur? [timing]
3. How regularly do they occur? [frequency]
4. How long would inundation last? [duration]

ANALYTICAL METHODS

Gage Data

A continuous dataset of stage and discharge was created for the mainstem Sacramento River at the upstream end of the Ship Channel Bypass. The I Street gage (IST), operated by the Department of Water Resources (DWR), is the closest gage to the upstream end of the Ship Channel Bypass. The IST data (downloaded from the California Data Exchange Center [CDEC] website) was recorded on an hourly data with the period of record beginning January 4, 1984. The conversion of hourly data to daily data was performed by averaging the hourly data in to a daily time series. Even when aggregating the data in this manner, the IST gage data was patchy and discontinuous.

Flow data

To fill the gaps in the flow dataset, a regression model was built by plotting between mean daily flow at IST with corresponding mean daily flow data continuously recorded at the upstream Verona gage (USGS#11435500) (Figure 2) (downloaded from the USGS website) (Figure 3). For the purposes of this analysis, a simple linear relationship was assumed.

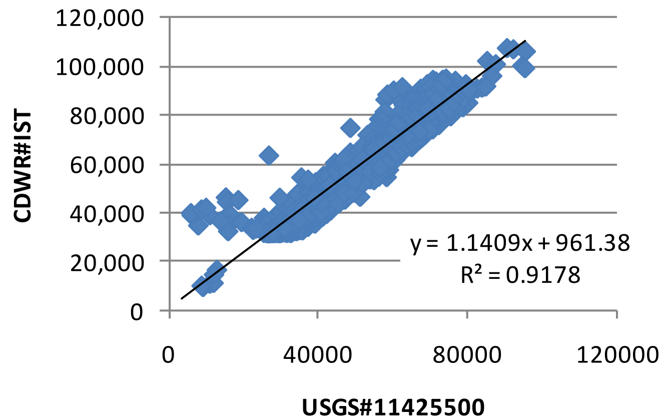

FIGURE 5: Correlation between flows (ft^3/s) at Sacramento River at Verona (USGS#11435500) and Sacramento River at I Street Bridge (CDWR #IST).

Stage data

To fill holes in the IST stage data a stage discharge relationship was developed based on the available stage data and the complete flow dataset previously described (Figure 5).

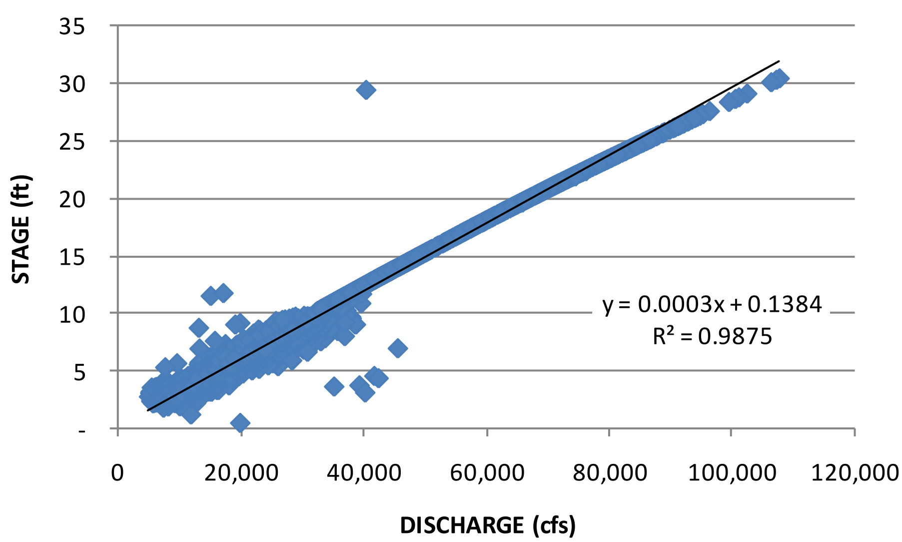

FIGURE 6: Correlation between stage and discharge at Sacramento River at I Street Bridge (CDWR #IST).

RESULTS

The full record of the measured (blue) and interpolated (red) flow and stage data for IST used for this analysis is presented in FIGURE 7 and basic characteristics of flow are presented in TABLE 1.

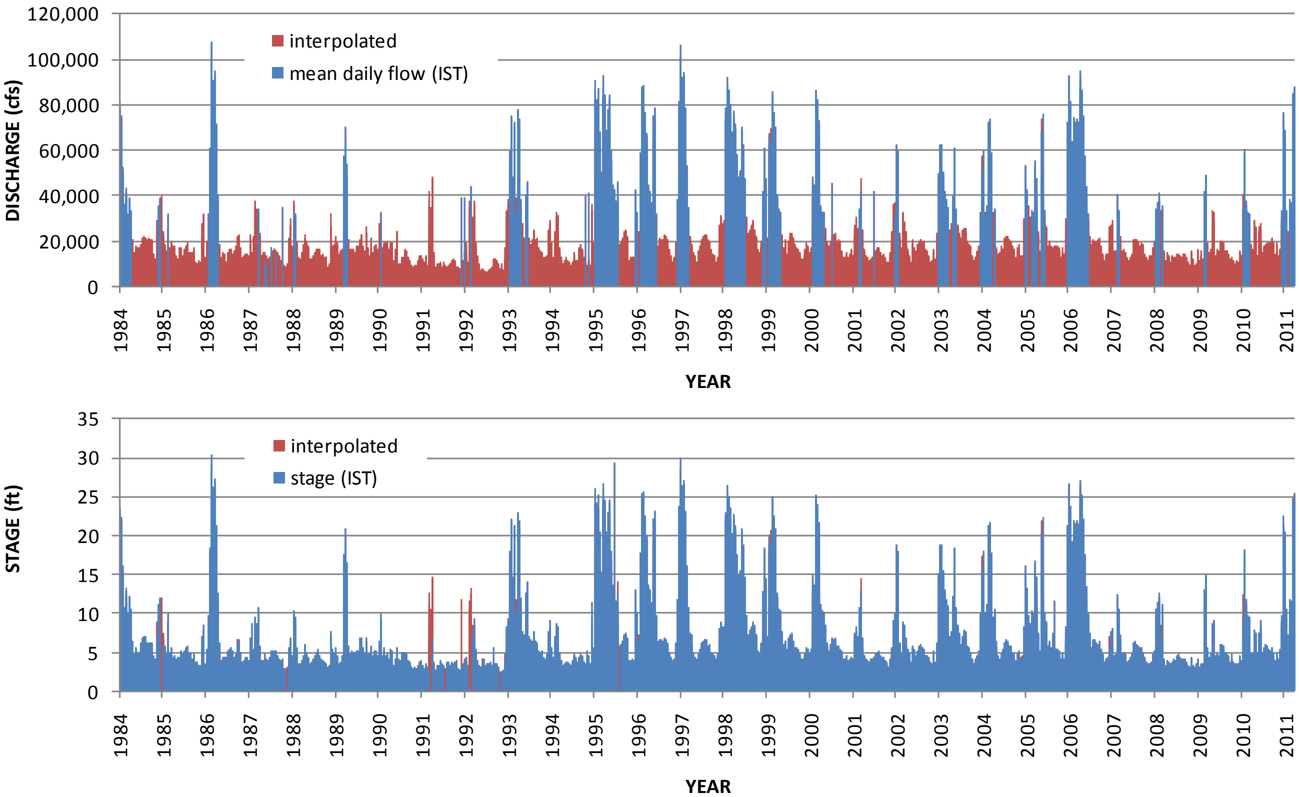

FIGURE 7: Measured and interpolated flow (top) and stage (bottom) data from the CDWR IST gage.

TABLE 1: Basic flow characteristics based on measured and interpolated data from the CDWR IST gage.

	Discharge (ft^3/s)	Date	Stage (ft)	Date
max	107,813	2/19/1986	30.46	2/19/1986
minimum	4,878	6/24/1992	1.17	4/9/2008
average	22,110		6.65	

By calculating the average daily flow (22,110 ft^3/s) it is possible to categorize water years as either Dry- (below average), Wet- (above average), or Normal-years. As an example, WY 2005 is determined to be a Normal-year (22,203 ft^3/s mean daily flow), WY 1998 is a Wet-year (39,506 ft^3/s), and WY 1991 is a Dry-year (11,303 ft^3/s) (FIGURE 8).

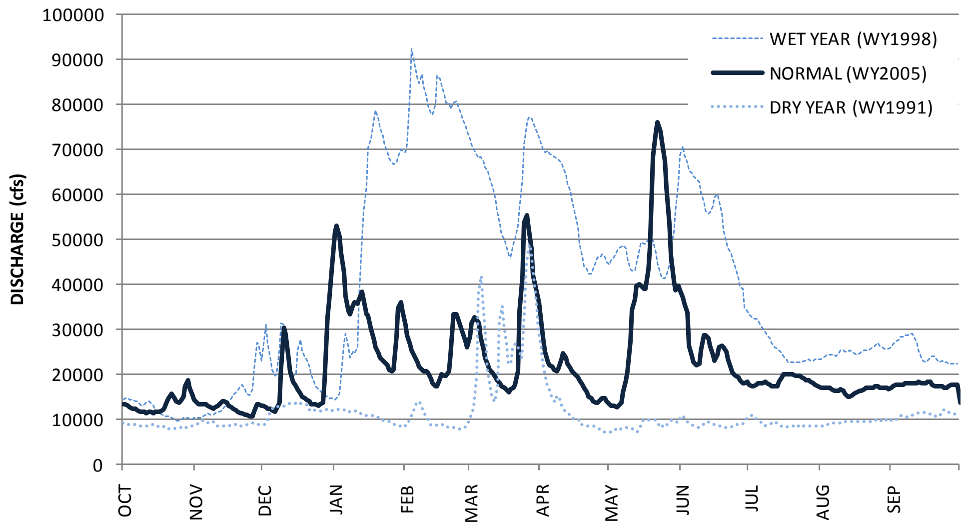

FIGURE 8: Hydrograph of Wet-, Normal- and Dry-years based on CDWR IST gage data.

ANALYSIS/DISCUSSION

Excess Flows

To answer the first question, “Are there excess flows that could be diverted onto the proposed bypass?” all 26 water years of flow data were plotted on the same axis (FIGURE 9) with a threshold of 27,000 ft^3/s which represents the minimum flow on the mainstem Sacramento that must be exceeded to spill into the Ship Channel Bypass (M. Matella, *pers. comm.* 2011)[1]. According to FIGURE 9, the minimum threshold of 27,000 ft^3/s has been exceeded for all 26 years on record, suggesting that excess flows exist on the mainstem Sacramento that could be diverted onto the Ship Channel Bypass to create an inundated floodplain.

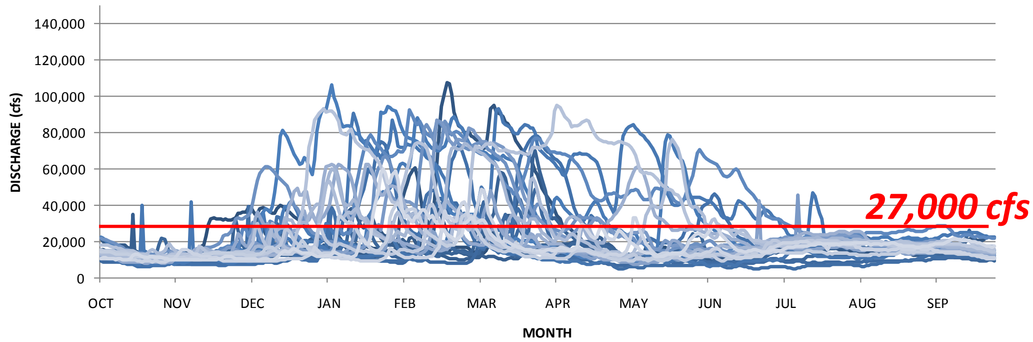

FIGURE 9: Discharge by water year for the entire period of record (WY1985-WY2010).

[1] The 27,000 ft^3/s minimum threshold was generated by first analyzing I-Street to stage data to extrapolate stage at the head of the weir, and then using a stage-discharge relationship to determine the flow needed to create a stage higher than the land surface at or near the head of the weir.

Timing of Inundation

Using FIGURE 9 as the base, FIGURE 10 shows the minimum threshold of 27,000 ft^3/s is exceeded most often from December to July. When compared to the expected agricultural and environmental uses in the bypass (FIGURE 11), this period of inundation corresponds with the periods of primary environmental uses by fish and wildlife.

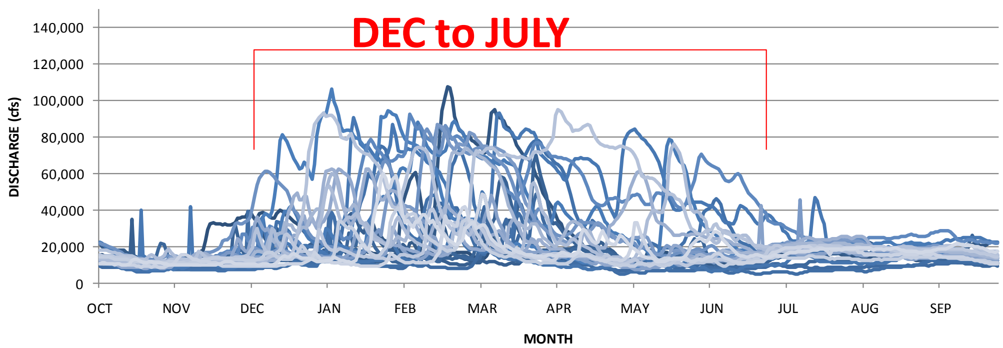

FIGURE 10: Discharge by water year for the entire period of record (WY1985-WY2010).

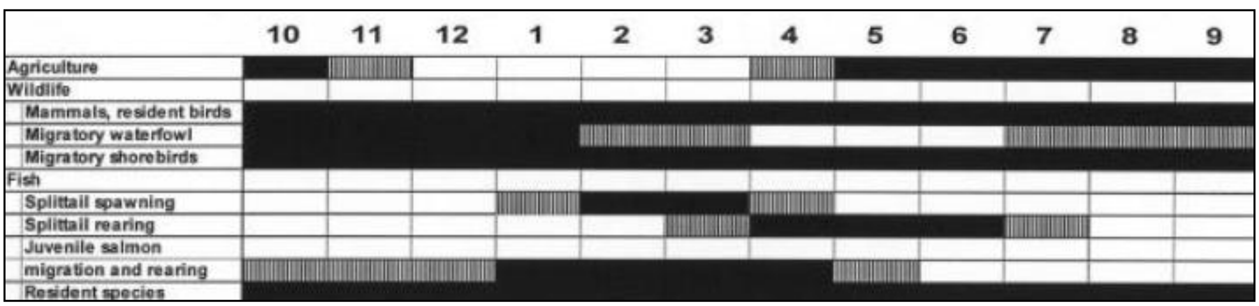

FIGURE 11: Agricultural and environmental activity in the Yolo Bypass floodplain by month. For agricultural and environmental uses of the floodplain, the primary (solid bars) and marginal (dashed bars) periods are shown. [Figure 2 from Sommer et al. 2001b]

Frequency and Duration of Inundation

Question 3 and 4 relate to the inundation potential of the bypass. 27,000 ft^3/s represents the *theoretical* minimum to overtop into the bypass and the dimensions of the weir will ultimately determine how much water will be diverted onto the bypass. In lieu of generating the engineering specs for a side-weir and doing a side-weir calculations, four flow scenarios were analyzed to provide a range of how regularly overtopping events might occur and how long they would last: 27,000 ft^3/s (minimum threshold), 30,000 ft^3/s, 35,000 ft^3/s, and 40,000 ft^3/s.

Frequency

Using the 26 years on record, FIGURE 12 shows how often each threshold was exceeded for each calendar day under each flow scenario. To get a better idea of the timing of inundation on the Ship Channel Bypass, the dataset was analyzed for how many years a given calendar day exceeded the threshold across the entire period of record for each of the scenarios (FIGURE 12). This provides the likelihood of inundation on a given day based on historical data. For example, you can see that in March, the threshold was exceeded 60-70% of the time.

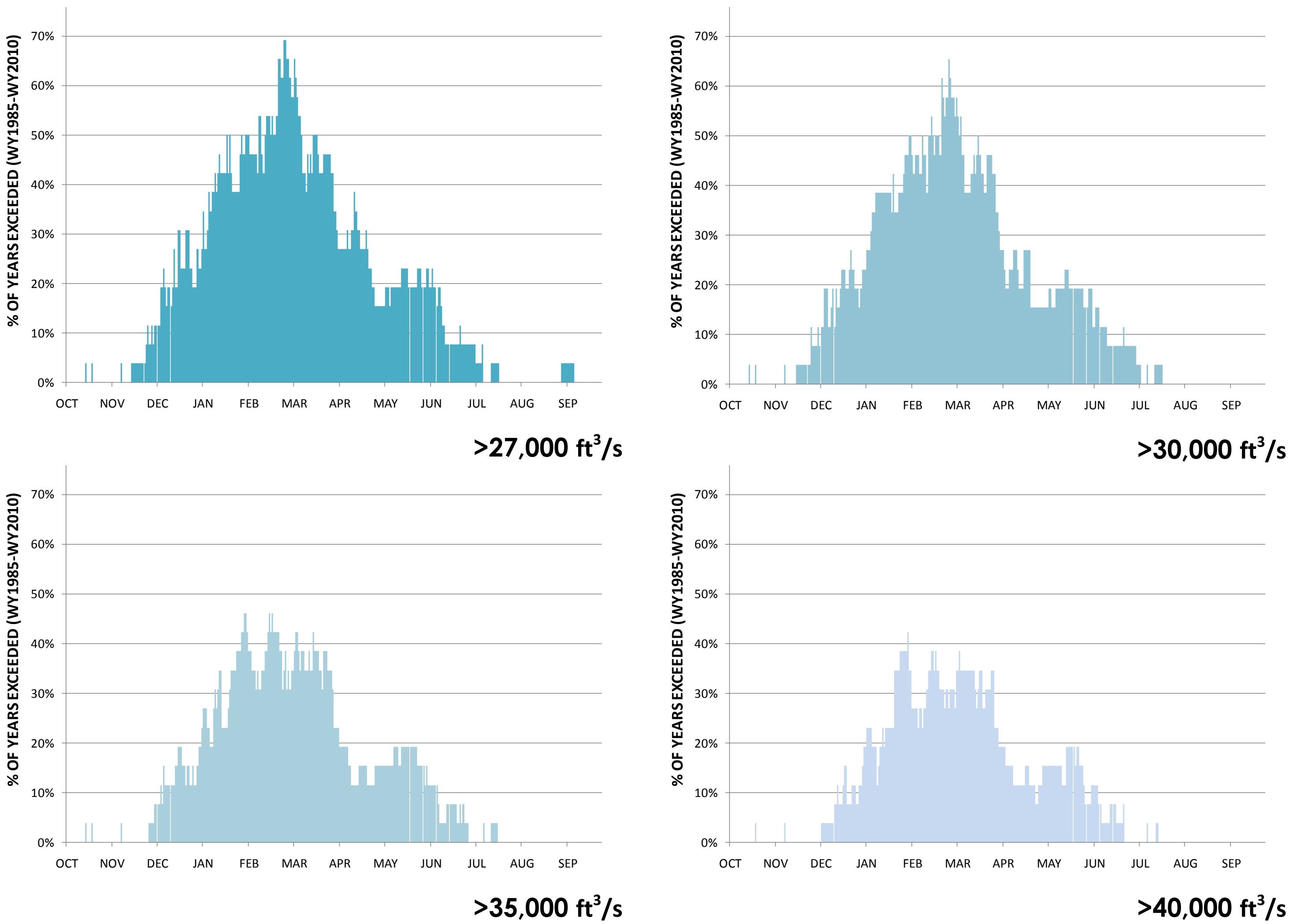

FIGURE 12: Percent of years flow threshold was exceeded on a given calendar day for the period of record (WY1985-WY2010).

Duration

How long an area is inundated is an important consideration when evaluating the new Ship Channel Bypass. As stated previously, many riparian plants have life history requirements which rely on certain flood characteristics; in addition, the duration of inundation will determine what habitats occur and which species they benefit. The following figures show the periods of possible inundation for the proposed Ship Channel Bypass for each of the four scenarios. Each chart shows when the threshold was exceeded for each water year. But, for question 4 which seeks to understand duration of inundation of the Ship Channel Bypass floodplain, the more important question to ask is *"How many consecutive days of floodplain inundation could be expected on the bypass?"* Furthermore, Northern California experiences a Mediterranean climate and as such, it makes sense to characterize the possible consecutive days of inundation based on the extreme conditions (wet and dry water years), as well as average conditions (normal water year) (TABLE 2).

TABLE 2: Maximum consecutive days of potential inundation that might be expected on the Ship Channel Bypass for a normal, wet, and dry year compared with total days of inundation (in parentheses) for each of the flow scenarios.

	Maximum Consecutive Days of Inundation		
Flow Scenario	**Normal[1]**	**Wet[2]**	**Dry[3]**
>27,000	26 (81)	181 (196)	7 (14)
>30,000	25 (67)	177 (180)	6 (12)
>35,000	23 (46)	168 (168)	6 (10)
>40,000	12 (25)	165 (165)	4 (5)

[1] WY1998
[2] WY2005
[3] WY1991

Across all flow scenarios, a normal water year on the mainstem Sacramento River could result 12−26 days of floodplain inundation on the bypass. A wet year could produce 165−181 days of inundation on the bypass while a dry year might only produce 4−7 days. The same wet, normal and dry years are highlighted in the following figures for comparison with the other water years on record.

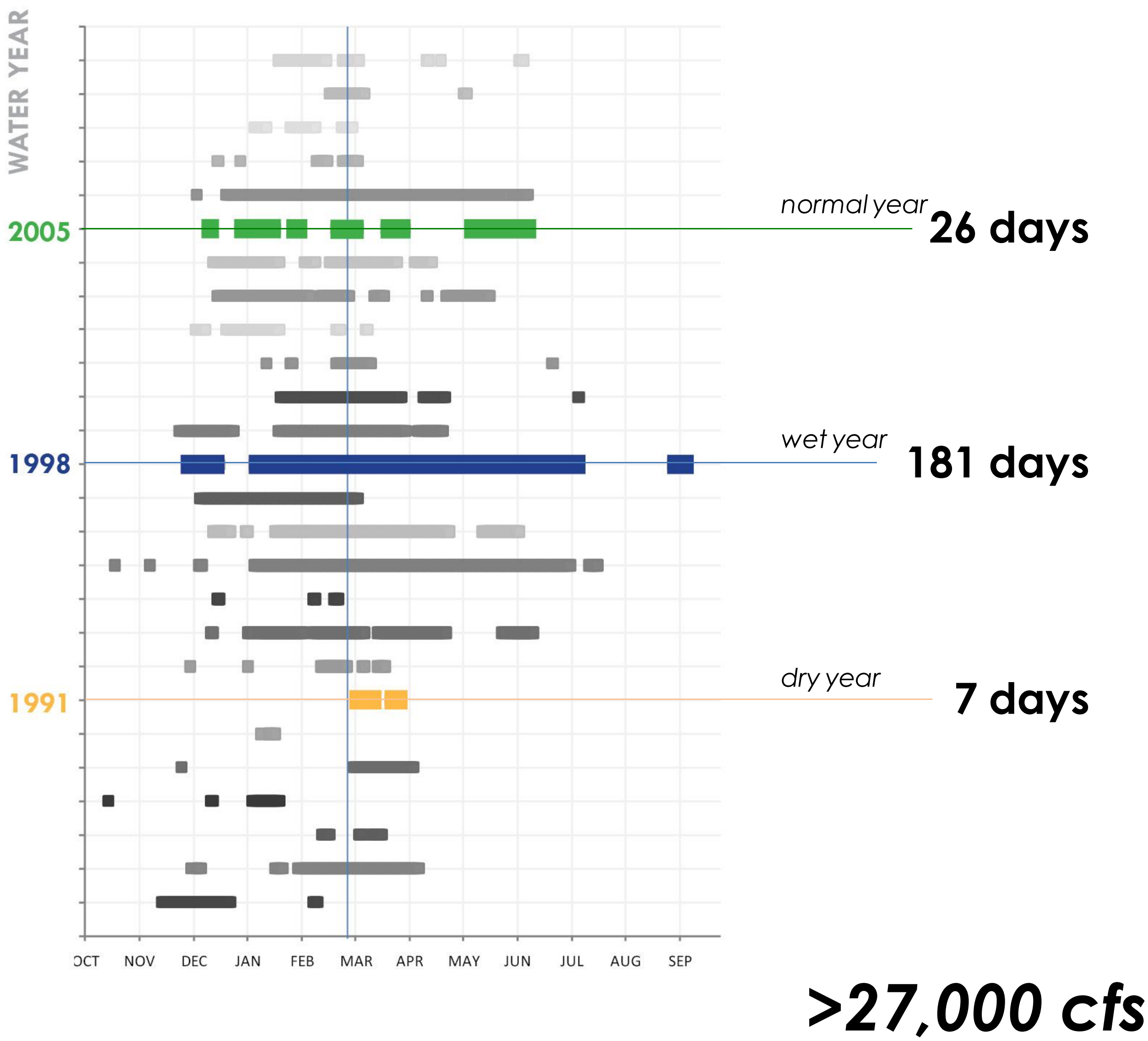

FIGURE 13: Periods of potential inundation for the Ship Channel Bypass (WY1985-WY2010) based periods where flow on the mainstem Sacramento River exceeded 27,000 ft^3/s. Maximum consecutive days of potential inundation are provided for a normal (green; WY2005), wet (blue; WY1998), and dry (yellow; WY1991) year.

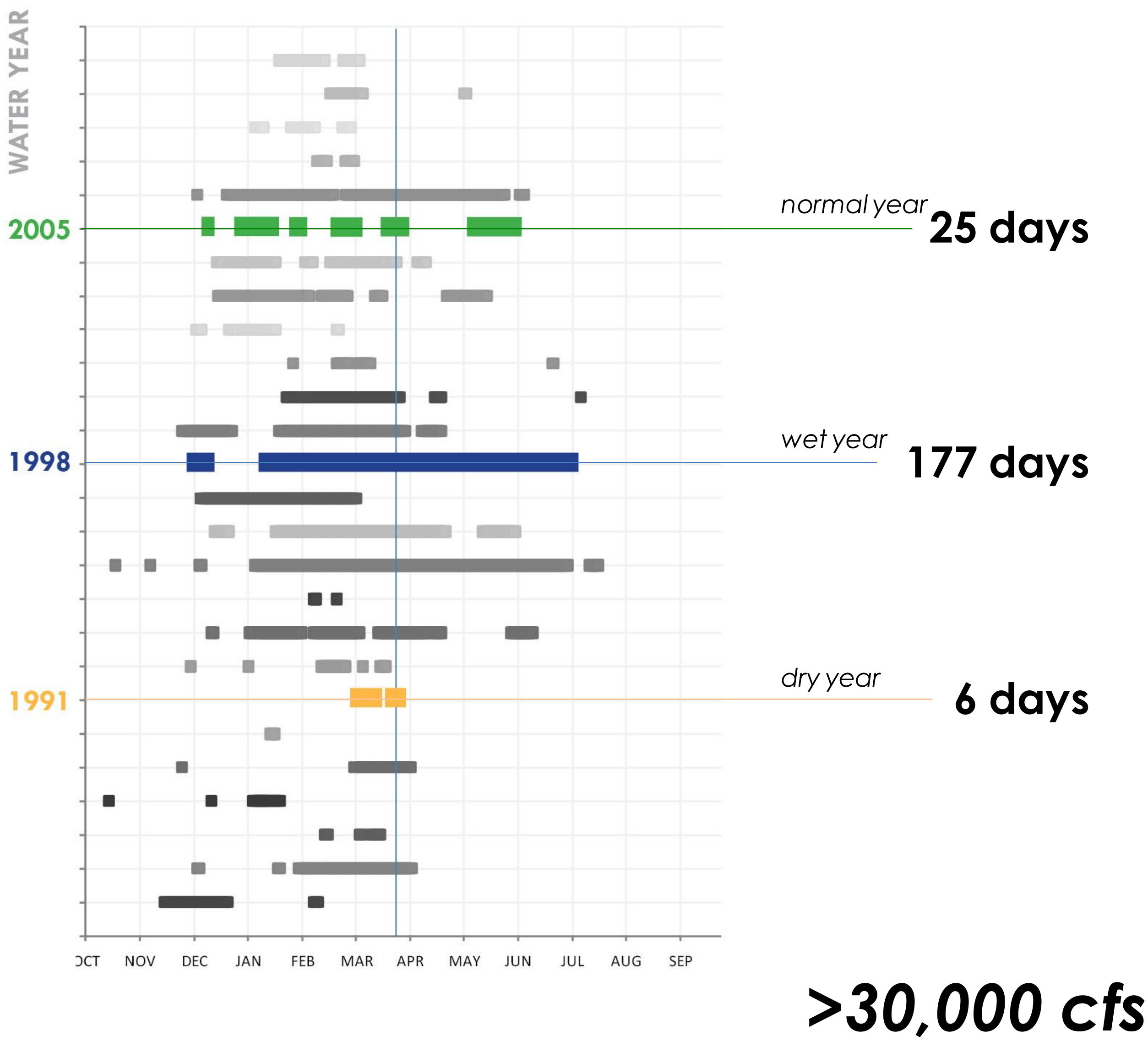

FIGURE 14: Periods of potential inundation for the Ship Channel Bypass (WY1985-WY2010) based periods where flow on the mainstem Sacramento River exceeded 30,000 ft^3/s. Maximum consecutive days of potential inundation are provided for a normal (green; WY2005), wet (blue; WY1998), and dry (yellow; WY1991) year.

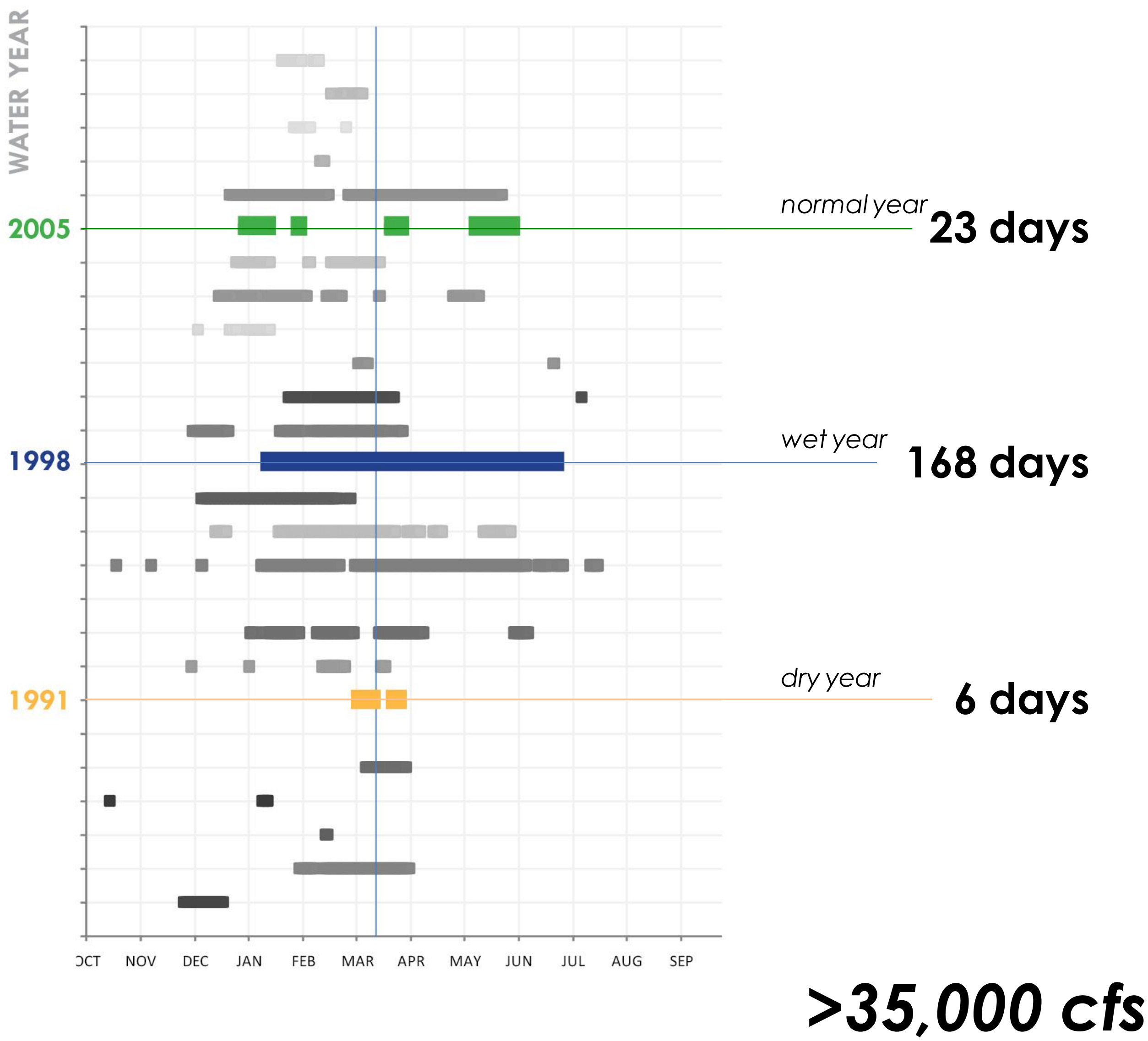

FIGURE 15: Periods of potential inundation for the Ship Channel Bypass (WY1985-WY2010) based periods where flow on the mainstem Sacramento River exceeded 35,000 ft^3/s. Maximum consecutive days of potential inundation are provided for a normal (green; WY2005), wet (blue; WY1998), and dry (yellow; WY1991) year.

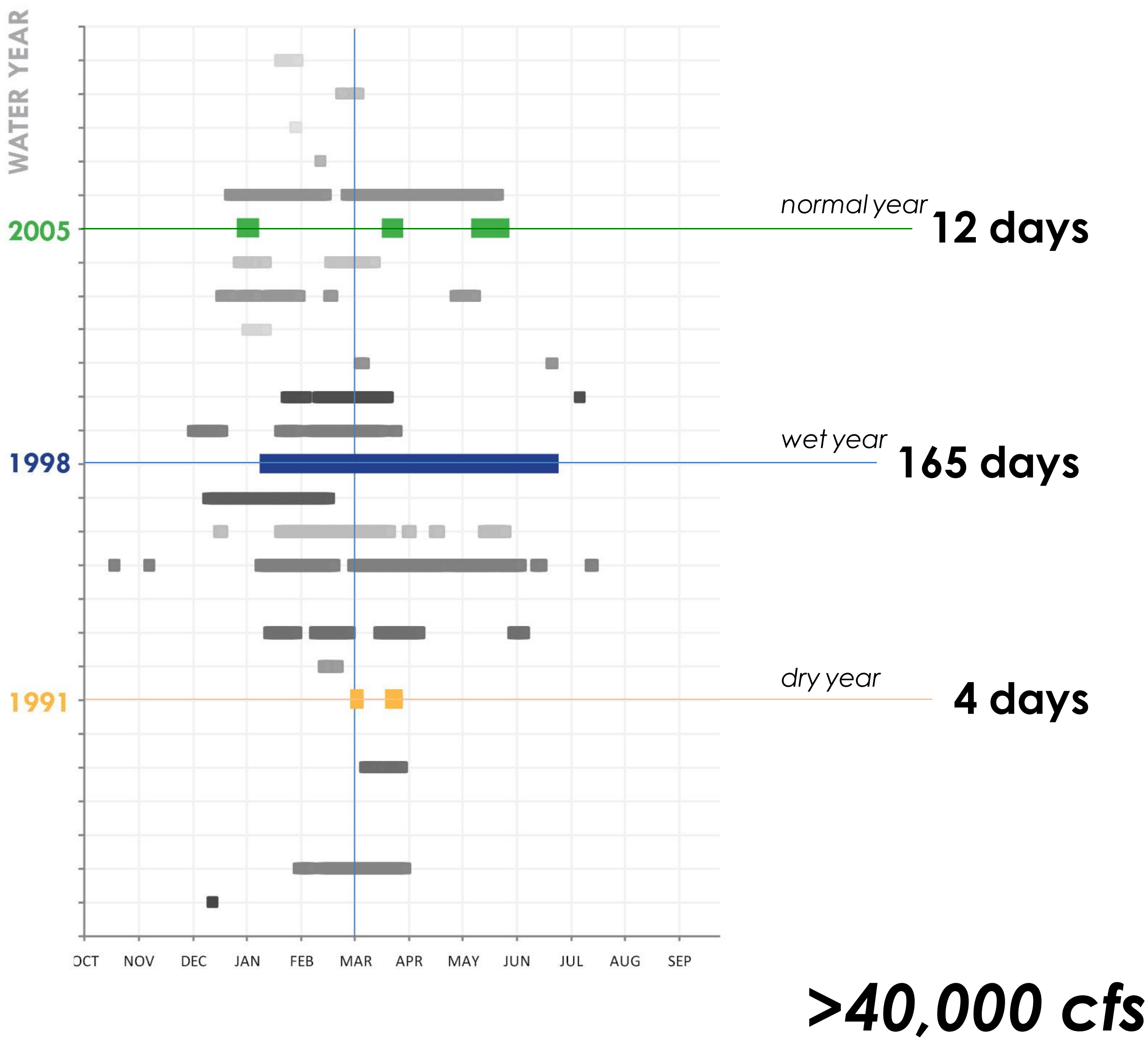

FIGURE 16: Periods of potential inundation for the Ship Channel Bypass (WY1985-WY2010) based periods where flow on the mainstem Sacramento River exceeded 40,000 ft^3/s. Maximum consecutive days of potential inundation are provided for a normal (green; WY2005), wet (blue; WY1998), and dry (yellow; WY1991) year.

CONCLUSIONS

This report shows that excess flows on the mainstem Sacramento River that could be diverted into the Ship Channel Bypass fairly regularly from December to July. Flows diverted onto the bypass could create inundated floodplain habitat for 4−7 days in a dry year and up to 165−181 days in a wet year. The results of this study have implications for the extent of floodplain and wetland habitat that could be restored on the proposed bypass as well as the species that could benefit from habitat restoration.

FIGURE 17 illustrates next steps that could be taken to inform the feasibility assessment of the Ship Channel Bypass. Furthermore, it can be an iterative process -- at the end of the proposed assessment process, planners can go back and conduct more in-depth analyses to test those assumptions and reduce uncertainty prior to implementation, or to improve desired outcomes.

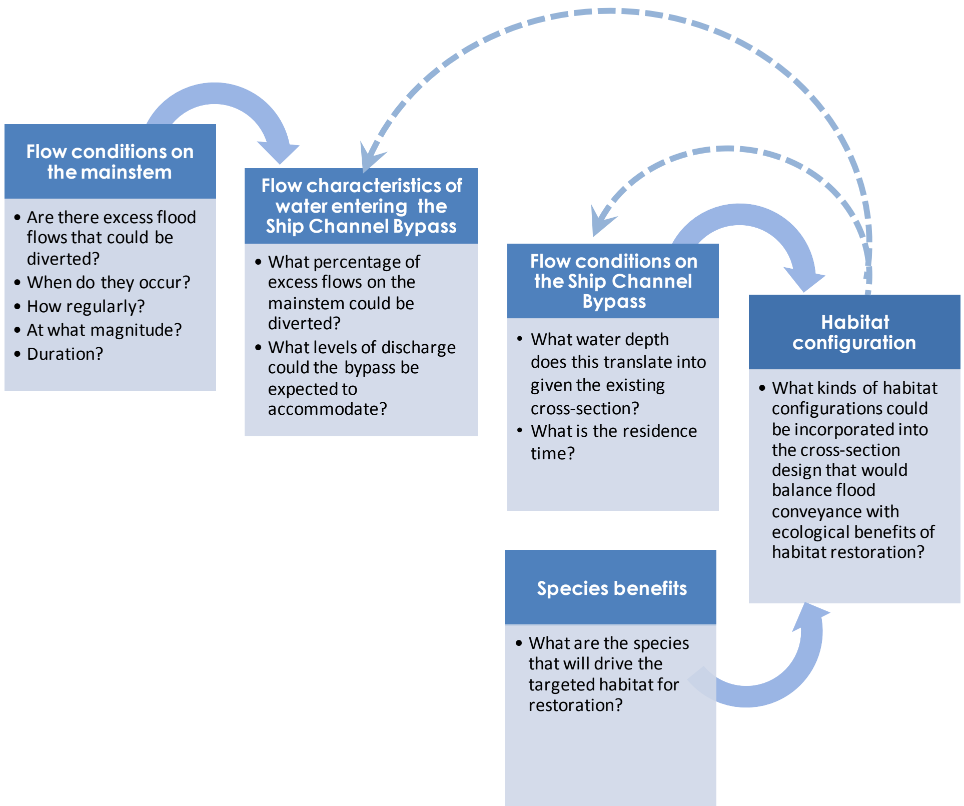

FIGURE 17: Feasibility assessment process and key questions to be addressed at each level of analysis to devise a plan that will provide floodplain habitat for fish and other wetland species. Dashed lines indicate an iterative process by which planners can incorporate new information and reassess and refine the process.

ACKNOWLEDGEMENTS

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REFERENCES

American Rivers. 2008. Deep Water Ship Channel Bypass narrative. DRAFT.

BDCP (Bay Delta Conservation Plan). 2008. Evaluation of North Delta Migration Corridors: Yolo Bypass. Technical Study #2. Prepared for the Bay Delta Conservation Plan Integration Team. DRAFT.

CDFG (California Department of Fish and Game). 2008. Yolo Bypass Wildlife Area Land Management Plan. Prepared by CDFG, Yolo Basin Foundation and EDAW.

Jenks, K. 2010. Ship Channel Bypass Technical Memo. DRAFT.

May, R.W.P, B.C., Bromwich, Y. Gasowski, and C.D. Rickard. 2003. Hydraulic design of side weirs. Thomas Telford Publishing, London.

NHI (National Heritage Institute). 2003. The Past and Present Condition of the Marsh Creek Watershed. Third edition.

Schemel, L. E., S. W. Hagar, and D. Childers. 1996. The supply and carbon content of suspended sediment from the Sacramento River to San Francisco Bay. Pages 237–260 *in*: J. T. Hollibaugh (Editor). *San Francisco Bay: The Ecosystem*. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.

Sommer, T.R., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001a. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26 (8): 6-16.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001b. Floodplain rearing of juvenile chinook salmon: evidence of enchanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2): 325-333.

Stillwater Sciences. 2005. Conceptual restoration design for the Merced River Ranch. Volume I: conceptual design report. Prepared by Stillwater Sciences, Berkeley, California, for CALFED, Sacramento, California.

USACE (U.S. Army Corps of Engineers). 2003. Supplement to the Standard Operation and Maintenance Manual, Sacramento River Flood Control Project (as revised 1995) for the Yolo Basin Wetlands, Project Modifications Works, Yolo County, CA.

USACE (U.S. Army Corps of Engineers). 2006. Office Report: Yolo Bypass 2-D Hydraulic Model Development and Calibration (Draft). U.S. Army Corps of Engineers Sacramento District.