Submission of Final Report

Integrated Flood Management for Climate, Salmon, Agriculture, and Community Resilience in the Lower Mainland

Prepared by: Saeed Mohammadiun, UBC Suitability Scholar 2022

Prepared for: Dan Straker, Project Manager of Resilient Waters, MakeWay
Lina Azeez, Habitat Programs Director, Watershed Watch Salmon Society

August 2022

DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of MakeWay and Watershed Watch Salmon Society staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of MakeWay and Watershed Watch Salmon Society or the University of British Columbia.

TERRITORY ACKNOWLEDGEMENT

The author acknowledges that much of the work for this project took place on the unceded ancestral lands of the Syilx.

The intention is that this work will, in some way, support Coast Salish First Nations from Tsawwassen to Seabird Island to aid in protecting their communities and cultures from the disproportionate impacts they suffer from both flooding and loss of salmon and ecosystems.

EXECUTIVE SUMMARY

The Lower Fraser Watershed is one of the most prolific salmon habitats in the world. However, a significant portion of these habitats became inaccessible to salmon due to over 150 pieces of ageing flood control structures, affecting hydrologic connectivity between the river and floodplains. Extensive systems of dikes, pump stations, and floodgates adversely impacted the lateral movement of salmon across the Lower Fraser floodplains. In addition, the legacy of extensive river-edge diking in the Lower Mainland disproportionally affects indigenous communities through the associated socio-economic consequences, such as locating their communities in at-risk areas, reducing storage capacity of floodplains, and decreasing salmon runs. Climate change has also exacerbated the circumstances via more severe riverine floods and sea-level rise in the area.

Incorporating integrated floodplain management (IFM) through a risk-based approach has been recognized as one of the most promising alternatives to traditional and hazard-based flood management approaches. While the traditional approaches significantly rely on purely structural protection in single-benefit projects, IFM focuses on nature-based alternatives along with wildlife-friendly engineering solutions within multi-benefit projects. IFM aims to reduce flood risk while having a holistic vision to collaboratively support major local and provincial values, such as agriculture, fisheries, vibrant economy, climate change resilience, and environmental justice. IFM reaches a shared vision among numerous stakeholders and affected communities that can lead to a set of actions building trust and mutual respect for the values of all involved entities. The built trust through the outcomes of the initial actions can engage more entities to achieve greater benefits for a wider range of stakeholders within larger-scale areas.

This study aims to conduct a literature review and develop several examples of integrated and collaborative flood management governance regimes that proactively consider climate change, ecosystems, food security, indigenous rights, and flood risk. Three case studies of IFM were reviewed to elaborate on the development and implementation of IFM-based approaches and present some valuable experiences from real-world programs and associated local projects. Two case studies in the United States (i.e., Floodplains by Design and Yuba Watershed) and one case study in New Zealand (i.e., Ōtākaro/Avon River Regeneration Corridor Plan) were reviewed. Each of the case studies provided unique challenges and solutions that can inspire a new way of managing for floods in the Lower Mainland.

This review outlines the broader concept and requirements of an effective regional-scale IFM and the interconnected relationship between IFM's regional and local levels. The major challenges in IFM implementation and potential associated solutions were also reviewed based on the hands-on experiences of practising IFM. The study summarizes significant steps and considerations to facilitate IFM as well as overarching concepts needed to practice IFM as a widely accepted norm. Several constructive strategies were gathered in this study to restore and protect fish and wildlife habitats while preserving agricultural lands. These strategies looked at the integration of multiple purposes and collaboration between numerous entities with historical conflicts to create a shared vision. In one case study the aim was to regenerate an abandoned area by considering the predominantly natural character of the land and the local indigenous values for sustainable management. Specific projects and examples of IFM implementation were also reviewed to explicitly indicate the benefits of IFM, such as a watershed-scale IFM and monitoring system; dike setback construction; self-regulating floodgates application; ditch and culvert relocation; native vegetation and wildlife habitat restoration; enhancing agricultural treatments; establishing various conservation easements; and seasonal inundation of farmlands. However, other IFM-based programs around the world can also be considered for evaluation in future studies to add to the knowledgebase around IFM implementation.

Multi-sector collaboration considering equally important values within IFM may lead to comprehensive and efficient solutions to flood risk and ecosystem issues. To implement an IFM-based approach, it is necessary to

- change the "entrenched pathways" towards the application of traditional approaches;
- build trust among all influential stakeholders and affected communities through a shared vision with specific objectives and measurable performance metrics;
- secure multi-source funding to develop plans and implement associated projects; and
- practice an adaptive management system by establishing a neutral backbone organization.

Overall, informing a cross-sector network about better flood management practices throughout the Lower Mainland may broadly improve the community, salmon, agriculture, and ecosystem resilience to flooding and climate change. This study provides informative examples of IFM and potential solutions to the current issues in the Lower Mainland that can be used by a wide range of local, provincial, and federal flood control authorities and practitioners to manage flood risk in a wildlife-friendly and collaborative manner.

Table of Contents

1. Introduction

At the end of one of the most prolific salmon rivers in the world, the lower Fraser watershed contains over 1,500 km of crucial habitat inaccessible to salmon due to over 150 pieces of ageing flood control infrastructure (including floodgates, pump stations, and dikes) many of which are in poor and failing condition. These flood control structures require thoughtful and careful planning to prepare communities for climate change impacts. Increased flooding and salmon loss significantly impact the economy, ecology, and society in the Lower Mainland and BC in general. First Nations along the Lower Fraser are disproportionately impacted by flood and loss of salmon, with many of these communities' reserve lands falling in at-risk floodplains.

Informing a cross-sector network about better flood management practices throughout the Lower Mainland may broadly improve the community, salmon, agriculture, and ecosystem resilience to flooding and climate change. Considering the flooding emergency in November 2021, it seems the Lower Mainland should be better prepared in terms of sufficient coordination, sustainable funding, and appropriate jurisdictional authority when it comes to flood management. To address the current complications of flood management, it seems necessary to develop a holistic vision through a collaborative approach achieving multiple benefits for a broader spectrum of stakeholders and affected communities.

This study aims to conduct a literature review and develop several case studies of integrated and collaborative flood management governance regimes that proactively consider climate change, ecosystems, food security, indigenous rights, and flood risk. To this end, major issues and potential solutions for flood management in the Lower Mainland were initially identified through evaluating the current conditions in this area. Following that, three promising case studies of integrated floodplain management (IFM) were reviewed to elaborate development and implementation of IFM-based approaches and present some valuable experiences from real-world case studies. Two case studies in the United States (i.e., Floodplains by Design and Yuba Watershed) and one case study in New Zealand (i.e., Ōtākaro/Avon River Regeneration Corridor Plan) were reviewed in the present research due to their unique challenges and associated solutions that can also be incorporated in the Lower Mainland. These case studies consider agricultural and fisheries values, vibrant community interests, climate change adaptation strategies, and indigenous rights within a collaborative flood management decision-making process. The availability of sufficient official documents in English and lacking comprehensive content analyses previously conducted on these case studies are additional justifications for their selection. Furthermore, several projects locally practiced under/consistent with the IFM plans were reviewed within US case studies, including agricultural floodplain pilot, levee setback, and tidal marsh restoration projects. These smaller-scale projects can explicitly exhibit positive outcomes of multi-benefit, collaborative approaches in flood management and illustrate aspects of local IFM practices with a higher resolution.

However, other suitable programs/projects worldwide can also be considered for further evaluation in future studies, such as Room for the River, LiLa (Living Lahn), Slowing the Flow, and so on. Room for the River was a €2.3 billion [CA$3.04 billion][1] IFM program initiated in 2007 to reduce flood risk through more than 30 projects in The Netherlands. These projects mainly aimed to set back dikes as well as establish flood bypasses and wider buffer zones, mimicking unimpaired hydrologic conditions of floodplains (Dutch Water Sector, 2022; Rijke et al., 2012; Van Herk et al., 2015). LiLa, standing for Living Lahn, is also an IFM program commenced in 2015 with an initial budget of €16 million [CA$21.12 million] and complementary funding of €27 million [CA$35.64 million] in Germany. The 240 km Lahn River is a main tributary to the Rhine River. The lower part of the Lahn River with 140 km length demonstrated a valuable potential for natural restoration. To this end, the LiLa - Living Lahn program aimed to enhance the river's water quality, ecological conditions, and hydrologic connectivity mostly through coordinated nature-based solutions to flood (Albert et al., 2019; BfG, 2020; European Commission, 2022; Schmidt et al., 2022). Slowing the Flow (commenced in 2009) is a relatively smaller-scale multi-benefit project in North Yorkshire, UK, demonstrating the capability of various land management strategies to reduce flood risk. The estimation of the required funding was up to £4 million [CA$6.24 million]. These management strategies (e.g., tree planting, wooden dam creation, etc.) increased the storage capacity of floodplains to reduce flow peaks at downstream areas (Forest Research, 2022; NY Moors National Park, 2022; Slowing the Flow Partnership, 2016).

2. Flood management conditions in the Lower Mainland

The frequency of extreme floods has increased around the world as climate change exacerbates global warming and leads to substantial sea-level rise (City of Vancouver, 2018; Yazdi et al.,

[1] All currency exchange rates considered in this study were based on values reported by google on August 10, 2022. The present values of budgets were not considered.

2018). Extreme flood events have also triggered significant concerns among BC stakeholders following the serious environmental and socio-economic consequences (Fraser Basin Council & Ebbwater Consulting, 2021b). In addition to more severe riverine floods in BC, the sea level is projected to rise 1.0 m by 2100 and 2.0 m by 2200 in relation to the sea level in 2000.

The Province of BC started organized flood-control activities in the 1970s under the Floodplain Development Control Program. However, this province-led approach shifted into a decentralized flood management approach by transferring authorities to local governments in 2003. In this direction, each local government is responsible for developing and implementing its own flood protection vision, objectives, and strategies while the federal and provincial governments establish funding programs and high-level guidelines (Fraser Basin Council, 2016a).

During all these years, flood management in BC significantly relied on structural protection strategies within a hazard-based approach, especially dike (also called levee) constructions. While there are more than 1,100 km of regulated dikes in BC, about 600 km are located in the Lower Mainland, protecting communities against Fraser River floods (Fraser Basin Council, 2016a; Fraser Basin Council & Ebbwater Consulting, 2021a). These structures were progressively constructed to protect more than 280 industrial and commercial structures, 700 businesses, and significant multi-family housing units merely within the Fraser River Foreshore area (City of Vancouver, 2018). In recent years, this system of dikes considerably reduced the costs and damages of flooding in some communities (District of Squamish & Kerr Wood Leidal, 2017). However, there is always a notable probability of malfunction/failure in these reliability-based designed structures that may generate a false sense of safety in heavily urbanized, industrial, and agricultural areas behind them (California DWR, 2014; Fraser Basin Council, 2016b; Mohammadiun et al., 2018, 2020). Dike penetrations (e.g., drainage pipes and road junctions) are the most vulnerable points of failure, requiring special considerations in terms of construction and maintenance (California DWR, 2014). Only 4% of built dikes in the Lower Mainland fully satisfy the latest provincial requirements, such as sufficient elevation with respect to climate change impacts (Fraser Basin Council, 2016a). Dike's regular inspection reports, maintenance, and rehabilitation also require significant resources, not easily available to most of the 106 diking authorities in this area (Fraser Basin Council, 2021).

Fig. 1 schematically illustrates some of the current flood management complications in the Lower Mainland. As shown in this figure, downstream dikes/sea walls can also intensify the negative impacts of a dike failure by trapping water behind these structures, forming a so-called "bathtub" (District of Squamish & Kerr Wood Leidal, 2017). Although structural protections play an important role to reduce flood damage, traditional dike constructions along rivers' edges can adversely affect wildlife habitats, water quality, flood risk, and fisheries resources (California DWR, 2014; Ecology, 2021; Knox et al., 2022). For example, river-edge dikes (Fig. 1) can hydrologically disconnect streams, rivers, and floodplains, and traditional pump stations may also block the migratory passage of anadromous fish, kill them, or both.

Fig. 1. Schematic presentation of the current floodplain management issues in the Lower Mainland

Moreover, while there are 30 different first nation communities in this area with 90 pieces of land, two-thirds of their reserve and treaty lands (i.e., 61) are highly susceptible to floods. As also depicted in Fig. 1, a considerable portion of these lands have no appropriate structural protections against overflowing (Fraser Basin Council, 2016a). Provincial and some local governments have recently taken necessary steps towards a more inclusive process to engage the indigenous communities in decision-making (District of Squamish & Kerr Wood Leidal, 2017; Fraser Basin Council, 2021; Fraser Basin Council & Ebbwater Consulting, 2021b). However, the colonization legacy exacerbated the flood management in this area by:

- pushing indigenous communities towards flood-prone lands without any protection;

- excluding them from the flood management decision-making process;
- neglecting cultural, spiritual, and historical values of indigenous people in flood management;
- reducing emergency and flood response capability of indigenous communities;
- lacking required data for flood-related analysis in reserve and treaty lands;
- misusing their insufficient knowledge about available management resources; and
- negatively impacting reserve and treaty lands, salmon habitats, and marine mammal habitats by implementing conventional flood-control strategies (City of Vancouver, 2018; District of Squamish & Kerr Wood Leidal, 2017; Fraser Basin Council, 2016b, 2021).

Due to the current issues in flood management, one of the worst-case scenarios of spring freshet in the Fraser River may lead to 110,300 ha of land inundation by 2100. This flooding scenario can cause a significant financial cost in this area (i.e., up to CA$32.7 billion) and disproportionately affect the indigenous communities (District of Squamish & Kerr Wood Leidal, 2017; Fraser Basin Council, 2016a).

IFM has been recognized as one of the most beneficial approaches for flood risk management, leading to better long-term protection against floods' impacts (Fraser Basin Council & Ebbwater Consulting, 2021b; TNC, 2016). Various studies highly recommend IFM implementation within a risk-based management approach as a promising alternative to traditional and hazard-based management approaches (District of Squamish & Kerr Wood Leidal, 2017; Fraser Basin Council, 2021; Fraser Basin Council & Ebbwater Consulting, 2021b).

An effective IFM aims to reduce flood risk while having a holistic vision to collaboratively support major local and provincial values, such as agriculture, fisheries, economic growth, water quality, climate change resilience, environmental justice, and vibrant community (TNC, 2014, 2016). IFM plans should be developed and implemented based on the shared values of all influential stakeholders and affected communities, including indigenous people, farmers and fisheries associations, local industries, local community members, and local, provincial, and federal entities (Ecology, 2021; Floodplains by Design, 2016). The Province of BC also encourages the adaptation of multi-benefit and risk-based flood management plans by incorporating the United Nations Sendai Framework and the United Nations Declaration on the Rights of Indigenous Peoples (Fraser Basin Council & Ebbwater Consulting, 2021b). Employing non-structural, nature-based solutions along with necessary, well-designed structural mitigative strategies is one of the key components of an effective IFM (Fraser Basin Council, 2016b).

There is a lack of comprehensive and consistent IFM plans and risk-based guidelines in BC (Fraser Basin Council, 2021). Even most of the Lower Mainland's municipalities have not yet appropriately incorporated flood management concepts into relevant bylaws (Fraser Basin Council, 2016b). In addition, Province of BC spent most of its flood protection budget from 2016 to 2020 on post-disaster recovery (69%) and structural mitigative strategies (22%). Meanwhile, non-structural strategies received a small portion of the funding programs (Fraser Basin Council, 2021). Overall, required flood construction levels, setbacks from a body of water, and land use and zoning regulations are frequently considered non-structural strategies in flood-related bylaws with many exemptions. These exemptions also reduce the socio-economic resilience of urbanized, agricultural, and industrial areas, particularly by increasing flood risk to the income sources, natural environment, and food security (Fraser Basin Council, 2016b). Some of the major challenges for developing and implementing a holistic flood management plan in the Lower Mainland can be enumerated as (City of Vancouver, 2018; Fraser Basin Council, 2016a, 2021):

- Tackling historic challenges caused by continuous development in floodplains over time.
- "Entrenched pathways" towards the application of traditional flood control strategies and hazard-based approaches.
- Lack of sufficient data, relevant guidelines, and planning templates needed by local authorities for comprehensive risk assessment and IFM.
- Securing sustained and multi-source funds and qualified human resources for comprehensive flood analyses and major flood-control projects.
- Effective coordination and engagement of diverse jurisdictional authorities across BC through a consistent provincial framework.
- Managing the dynamic nature of flood hazards due to climate change and sea-level rise by implementing short-term and long-term suitable strategies.
- Building sustained trust with various influential stakeholders and affected communities, such as agricultural and fisheries associations and indigenous communities, to share the same vision.
- Land and right-of-way acquisition to implement various flood-control strategies.

The following sections review several successful case studies of flood management to provide informative examples of IFM and potential solutions to the current issues in the Lower Mainland.

3. Floodplains by Design Case Study

3.1. Introduction

The Floodplains by Design (FbD) program aims to improve the resilience of 17 main river floodplains in the Puget Sound region within the approximate area of 381,000 acres in the State of Washington, US. Multiple benefits of human safety, ecosystem enhancement, salmon recovery, agriculture protection, clean water availability, outdoor recreation, and vibrant economy are the main concerns of FbD (TNC, 2014, 2016). FbD has been a successful program mainly due to a proper public and private partnership, its productive collaboration with indigenous communities and environmentalists, and the FbD grant establishment to advance its vision and objectives. The FbD's appellation is rooted in the IFM concept, shifting from isolated management efforts with unforeseen consequences into a well-designed, holistic approach to obtain multiple benefits (TNC, 2018b). Within this case study, IFM is defined as "*an approach to floodplain management that leverages collaboration based on shared values in order to adopt new approaches to reduce flood damages, increase salmon runs, and preserve farms and open spaces that enrich our lives and create a resilient future*" (Ecology, 2021). This case study explicitly depicted the broader concept and requirements of an effective regional-scale IFM and delineated the inextricable relation between IFM's regional and local levels. The major challenges in IFM implementation and potential associated solutions are also reviewed within this case study based on the experiences obtained so far by practising IFM in the study area.

More than any other natural hazards, different types of floods (i.e., flash flooding, spring freshet, and king tides/storm surge coastal floods) caused significant financial burdens within the State of Washington. In Western Washington (i.e., west of the Cascade Mountains), prolonged winter storms are one of the main causes of flooding (Ecology, 2021). In the wake of practising traditional, single-objective flood management strategies for a long time (e.g., river dredging and diking) fish and wildlife habitats were degraded and developed communities were exposed to significant flood risks (Ecology, 2021; TNC, 2018b). The loss of river edge and off-channel habitat is one the most influential factors that reduce available rearing ponds for anadromous fish, limiting salmon recovery plans in the studied area (TNC, 2014). In recent years, flood management in the

State of Washington shifted towards a more holistic and integrated approach, especially emphasizing ecological restoration on entire watershed, inclusion and indigenous rights, collaboration among broader stakeholders, and climate change considerations (Ecology, 2021).

Puget Sound floodplains were among the first locations in this state descended by European settlers during the 1800s because of the rich soil and desirable water transportation potential. The Puget Sound region almost extended between the US-Canada border to the north and the City of Olympia to the south (Fig. 2). It is also located between Cascade and Olympic mountains from east to west. Puget Sound's coastal shoreline is a part of the Salish Sea, providing beneficial access to the straits of Juan de Fuca and Georgia from its northwest side. These days, the Puget Sound region has accommodated more than 4 million people within diverse land uses and extensive infrastructures, including 1000 critical public facilities. Some major floodplains in order of land area are Skagit, Snohomish, Nooksack, and Puyallup watersheds. All these floodplains comprised many natural habitats of salmonids' threatened species, particularly Chinook salmon (TNC, 2014). Multiple stakeholders of different counties such as Skagit, King, Pierce, Whatcom, and Snohomish Counties are among the major local entities in the area.

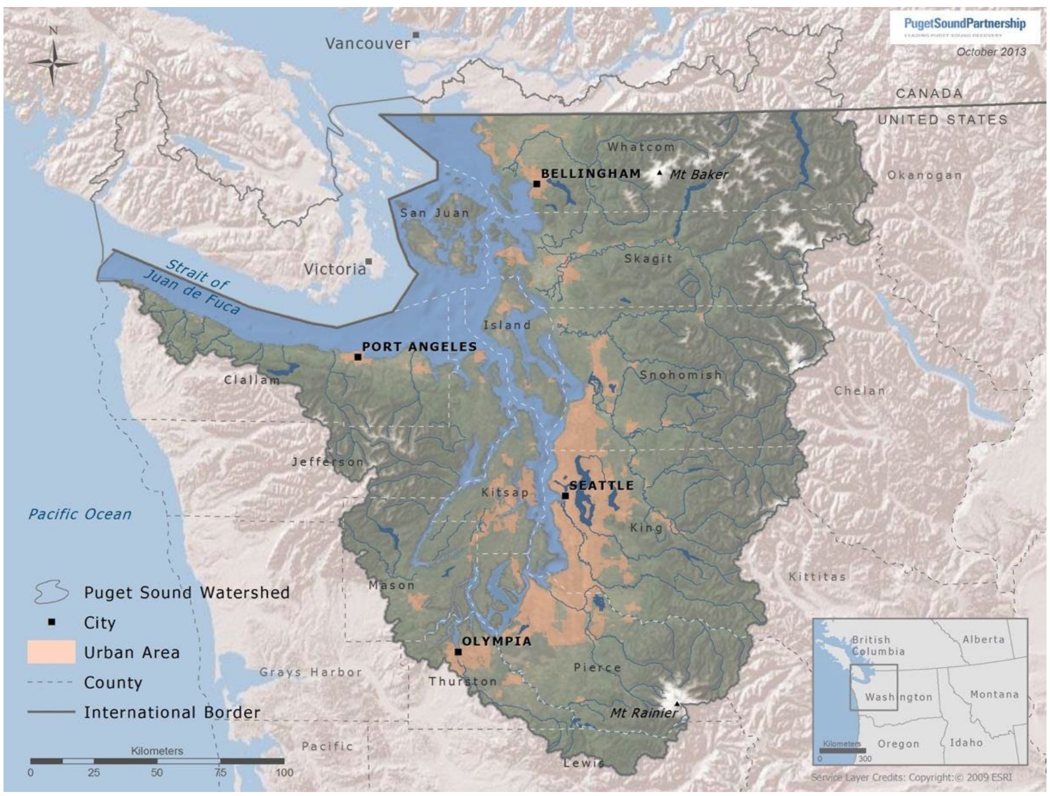


Fig. 2. The Puget Sound Watershed

Source: Encyclopedia of Puget Sound at the University of Washington Puget Sound Institute - originally published by Puget Sound Partnership

While the settlement and population growth initially provided the area with economic benefits, it increased the flood risk, deteriorated water quality, and declined fisheries over the past several decades. Besides, climate change has already impacted this area by flooding lands more frequently, reducing agricultural production, and changing streamflow regimes that negatively affected the salmon migration cycle (TNC, 2014, 2016). The major floodplains of this area contain more than 800 miles of rivers. Hence, the Puget Sound floodplains are extensively prone to riverine flood risk, and numerous main rivers lack sufficient hydrologic connectivity between rivers and floodplains. Rivers are hydrologically disconnected from the floodplains due to the extensive construction of dikes, dams, and roads in the area (TNC, 2014). The extensive system of dikes also left the local flood practitioners with expensive maintenance and rehabilitation costs, higher flood risks, and conflicting policies and regulations of state and federal organizations (TNC, 2018b).

To resolve these challenges, the local and regional stakeholders needed to reach shared values through a holistic and collaborative approach. Otherwise, a single interest of one entity may threaten other stakeholders' values, hindering the successful implementation of plans and projects. The FbD program provided this opportunity by practising multi-benefit, integrated strategies that can complement each other and attain greater support from multiple entities due to being more cost-effective. The most cost-effective solution to attain multi-benefit IFM in this area was recognized as reconnecting and protecting the floodplains by making more room for the major rivers. In this direction, the IFM goals have been achievable in this area through the following general practices (TNC, 2014, 2016):

- restricting the development of natural/working lands by zoning strategies or easement[2] acquisitions;
- improving water quality by adopting agricultural best management practices and developing buffer zones;
- maintaining and increasing open spaces by implementing different strategies such as setback dikes; and
- upgrading flood control facilities and increasing natural flood storage.

From 2013 to 2017, FbD initially focused on stakeholders' engagement, collaborative planning, knowledge-dissemination among stakeholders, grant program establishment, and local project

[2] Different types of easements are explicitly explained in Yuba Watershed Case Study

implementation. These activities proved the valuable IFM capacity to efficiently achieve multiple benefits (TNC, 2018a). During this period, different real-world examples demonstrated that this multi-benefit approach was more likely to be supported by a wide range of entities with increased funding for its implementation. Two successful examples were the Calistoga Levee Setback project in the City of Orting, which significantly reduced flood risks and restored salmon habitats, and the successful application development for HUD[3] resilience grant to be used in capital projects in Puyallup (TNC, 2014, 2016). The second five years (2018-2023) have been and will be focused on promoting IFM as a widely accepted norm in the watershed by changing policy and regulatory tools and expanding funding and human resources in support of IFM advancement (TNC, 2018a).

3.2. Significant challenges to practising Integrated Floodplain Management

An online survey was conducted in this area to identify major challenges to implementing an integrated, collaborative flood management system. A considerable number of local and regional entities participated in this online survey. The following items were identified as the significant challenges to practising an effective IFM (TNC, 2014):

- Lack of appropriate local IFM's vision, objectives, and strategies.
- Conflicts between local, regional, and federal policies and regulation tools as well as the requirements of programs and funding resources.
- Inadequate protection of floodplains through policies and regulation tools (e.g., some land-use policies impeding the optimum solutions for salmon recovery).
- Insufficient available funding to facilitate IFM implementation. The estimated funding gap at the initial stages of FbD was more than US$1 billion [CA$1.28 billion] over a period of 10 years.
- Uncertain, high-priced, and time-consuming process for permitting projects proposed under IFM, in which regulators have no internal deadline or standard assessment framework.
- Lack of sufficient incentives and appropriate easements for making a strong partnership with landowners to effectively practice IFM.
- Lack of sufficient local and regional capacity in terms of staffing level, technical skills, and governance structure to timely implement large-scale, collaborative projects and strategies.

[3]The U.S. Department of Housing and Urban Development

A well-organized methodology to practice IFM may address some challenges mentioned above. To this end, the next section defines various essential components of local IFM and suggests a cyclic structure of collaboration to promote a progressive integrated flood management system. Additionally, explicit strategies are provided in the next section to advocate IFM as a valued norm within a watershed.

3.3. A methodology to practising Integrated Floodplain Management

The concept illustrated in Fig. 3 was suggested within this case study to practice an effective IFM as an ongoing, non-linear process (Ecology, 2021; Floodplains by Design, 2016). This figure depicts four general components of IFM, including Floodplain Process Leaders, Watershed Scale Entities, Authorizing Intuitions, and Project Level Work, all of them mutually affecting each other. Floodplain Process Leaders manage and coordinate the collaboration among all involved stakeholders, for example, by organizing various conventions. The Nature Conservancy (TNC) plays this role in the present case study as the administrative backbone of FbD. The lead and implementing organizations need in-house staff with a variety of skills, such as flood-related technical skills, project management skills, the ability of proposal and grant writing, storytelling[4], data management[5], etc. Watershed Scale Entities comprises representatives of all stakeholders and affected communities, such as indigenous communities, local, regional, and federal agencies, non-governmental organizations, and other local community members. This group defines the local visions and objectives of IFM and prioritizes the implementation of approved local projects to practice IFM in the area. Authorizing Intuitions include local, regional, and federal decision-makers with political influence and/or considerable funding and policy control capacity. This could be cities and regional officials, leaders, and councils. Extensive collaboration between Authorizing Intuitions and other components is essential to secure sustained funding programs and establish appropriate regulatory systems (e.g., through changing policies) in order to support plans and projects. The Project Level Work is required to practice the IFM projects on the ground. The local projects will be designed and implemented within a reach (e.g., a specific length of a river) to support IFM's vision and objectives after establishing the required agreements/easements and permits (Floodplains by Design, 2016).

[4]A sympathy-based storytelling may lead to a better understanding, respect, and collaboration among entities with different interests (TNC, 2018b).

[5]Data management is an essential and complex process to enhance transparency and integration level through depicting the outcomes of different efforts in one place (TNC, 2018b).

Based on the experiences of this case study, the above-mentioned components are willing to collaborate through an integrated management cycle to practice IFM effectively. A discussion, agreement, and action series among all local, regional, and federal stakeholders build momentum towards IFM. Subsequently, more stakeholders will be involved, and more significant suits of multi-benefit actions will be practised over time. Within this cycle, the initial discussion and its subsequent agreement on a shared vision will lead to a set of initial actions promoting the interests of already engaged stakeholders. Discussion among interested entities builds trust and mutual respect for the values of each other. The actions can vary from submitting a preliminary IFM grant application as an initial action to a dike setback capital project as an example of a concrete action. Although the initial actions may be less integrated, their outcomes strengthen the trust among engaged entities and attract a broader set of stakeholders to IFM. From this perspective, it is necessary to take some initial smaller-scale actions, monitor the outcomes of these actions, and share the potential outcomes to make stronger partnerships that generate the essential momentum.

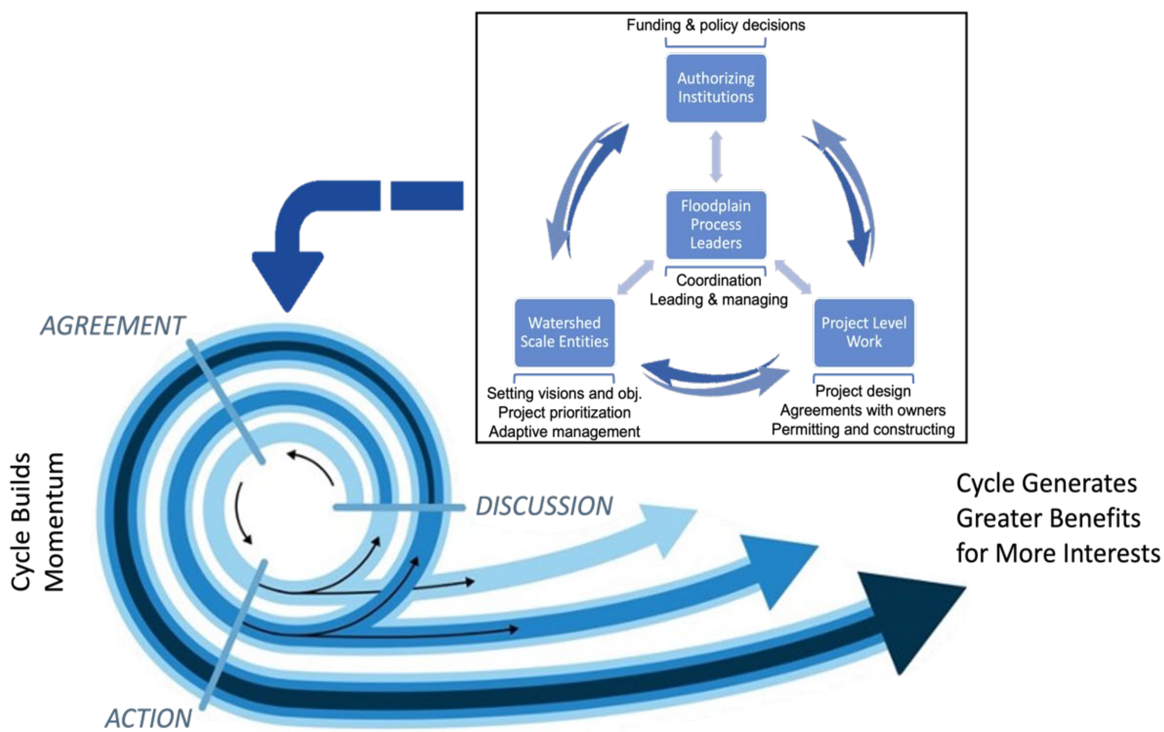


Fig. 3. The IFM cycle and significant components of integrated, collaborative management (Ecology, 2021; Floodplains by Design, 2016; TNC, 2018b)
Original Source: FbD Integrated Floodplain Management Status Report prepared by TNC collaborating with Ecology and Puget Sound Partnership within FbD

Moreover, further in-depth discussions will be required among engaged local entities on reach-scale agreements and project-scale actions after the initial watershed-scale agreement. As more stakeholders are involved, it may be necessary to step back in order to redefine the shared vision and objectives to include the needs of newcomers within this non-linear process (Ecology, 2021). Although IFM usually works more effectively on a larger scale by involving a broader range of interests and voices, achieving an overall and fully integration level requires long-time efforts (TNC, 2018b).

Following steps/considerations can facilitate IFM practice through "persistence, flexibility, and patience" of stakeholders (Ecology, 2021; Floodplains by Design, 2016; TNC, 2014, 2016):

- Identify stakeholders within both watershed and reach scales, and define the problem.
- Convene identified stakeholders in parallel with conducting technical studies to determine values and measurable performance metrics concerning IFM performance metrics in both watershed and reach scales[6].
- Advance regional agreement on shared vision and objectives by integrating flood management efforts and incorporating climate change considerations.
- Skillfully build trust at various scales concerning historical and emotional conflicts[7].
- Identify and celebrate successful outcomes of collaborations, preliminary from smaller-scale actions.
- Commit to the shared vision and objectives to pass the visioning step and reach solutions.
- Implement adaptative management actions to achieve greater benefits for more interests and increase organizational resilience[8].

Moreover, five overarching concepts should be considered for a system transformation to practice IFM within a watershed as a widely accepted norm. A system transformation may include changes in policies, funding programs, human resources, regulatory tools, and so on. These broad concepts, relevant goals, and potential associated strategies to promote them are listed in Table 1 (Ecology, 2021; TNC, 2018a). The backbone organization, as the process leader, plays a significant role in managing resources and collaboration among all involved entities to practice the suggested strategies in Table 1. These strategies aim to promote the overarching concepts at various local,

[6]Note that the necessary trust and momentum may be lost without an informative system of progress monitoring

[7]To this end, develop an action plan initially funding and implementing the projects that are more likely to build trust and consensus within involved entities

[8]Adaptive management can be practised by leaders and regional organizations through integrating multiple projects and funding sources, continuing to identify priorities within the action plan, and enhancing the continuous collaboration among entities

regional, and federal scales. Suitable and simple performance metrics of success can also be defined for each overarching concept to monitor and evaluate the progress towards advancing integrated management in a watershed. The performance metrics can be obtained through annual or biennial surveys among members of involved entities and affected communities to assess progress toward widespread IFM. Watersheds' per cent engaged in pursuing multi-benefit projects; average processing time for IFM-related permits; number and diversity of decision-makers attending training sessions to increase the IFM adaptation capacity; the amount of grants and funding from governments allocated to IFM projects; and the number of comments made by the public to support public investment in IFM are examples of a performance metric for each overarching concept, respectively (TNC, 2018a).

Eventually, it should be noted that both local and regional integration efforts are in great demand to implement a successful, fully integrated floodplain management. These efforts mutually affect and complete each other. Regional integration efforts will define the context within a larger area and support the successful long-term practice of local integration efforts. The regional efforts comprise integrating provincial and federal policies and regulatory tools, permitting processes, and funding and incentive programs. Alternatively, local integration efforts identify practical issues to implement IFM on the ground that can merely be addressed at a regional level. In this direction, local efforts inform regional efforts to conduct an effective regional integration (TNC, 2018b).

3.4. Development process, vision, and objectives of Floodplains by Design

A wide range of local and federal agencies as well as indigenous and local communities collaborated with the FbD management team (i.e., TNC, Washington State Department of Ecology, and Puget Sound Partnership agency) to establish the FbD program in the area. The Environmental Protection Agency and National Oceanographic & Atmospheric Administration were among the most influential federal agencies supporting FbD (TNC, 2016). While TNC has been acting as the backbone of the program to administer the regional practices toward IFM, the Department of Ecology initiated an FbD grant to provide various counties with the required financial support to implement IFM through multi-benefit projects (TNC, 2018a).

A 10-year regional vision has been considered within FbD to assist the current and future local efforts towards IFM, respecting multiple local values of communities in each major river corridor (TNC, 2014). To define the integrated vision and objectives of FbD, the local experts and flood practitioners in the area collaborated with Puget Sound's regional-scale stakeholders through a series of meetings and workshops. The current local conditions of floodplain management and expected outcomes of local multi-benefit projects in the next ten years were determined within this collaboration. Four main categories of floodplain management strategies to achieve multi-benefit (i.e., “Protect, Improve, Significantly Modify, and Maintain”) were developed in collaboration with local entities. “Improve” and “Significantly Modify” were local entities' most popular floodplain management strategies.

Then, the local entities used the four key strategies to categorize each floodplain reach within their authorization area. A reach scale is a sufficient and reasonable scale to initiate the implementation of IFM through several multi-purpose capital projects and/or some minor single-purpose projects, all merging towards optimized interests of all stakeholders. Following that, local entities were asked to develop local Floodplain Vision documents delineating their IFM reach-scale strategies.

Following this engagement process, the integrated vision and objectives of FbD were determined based on the local visions in the area. “*The Floodplains by Design partnership envisions a future 10 years from now in which:*

- *A transformation of Puget Sound’s floodplains is underway to reduce flood risk and restore habitat at an unprecedented scale. Spurred by a regional vision of resilience and revitalization and $1 Billion in new investments, reach-scale integrated plans to achieve flood risk reduction, habitat restoration and other floodplain improvements are being implemented.*
- *Floodplain actions are enabled by locally-driven plans, increasing political support, strategic and efficient program management, strong local-state-federal coordination, and a proven track record of results.*” (TNC, 2016)

The long-term vision of the FbD program is expected to be achieved by several objectives in terms of climate change adaptation, ecosystem restoration, vibrant community, and successful collaborations between stakeholders (TNC, 2016).

Climate change adaptation strategies may enhance human and infrastructure safety, farmland protection, and community resilience to natural hazards. Ecosystem restoration strategies, as the cornerstones of FbD, can improve water quality, fish and wildlife habitat, and the sustainability of salmon runs (Ecology, 2021; TNC, 2016).

Table 1. Overarching concepts and their associated goals and strategies to make IFM a norm (Ecology, 2021; TNC, 2014, 2016, 2018a)

No.	Concept	Goal	Strategies
1	Collaborative Culture	Broaden the network, especially with vulnerable and indigenous communities and get the support of local communities to accept the trade-offs to do the projects	- Identify vulnerable communities at risk of flooding and climate change and develop local adaptation strategies - Develop and implement appropriate persistent communication and outreach strategies, geographically expand IFM to all major reaches, and celebrate successful actions - Convene a Leadership Group from all entities to support local IFM by increasing regional/federal support - Develop IFM's website to share and collect information - Engage diverse agricultural and fisheries associations in IFM meetings and compensate them for attending - Identify reliable sources trusted by farmers to incorporate agricultural values effectively
2	Local Capacity	Provide sufficient technical capacity, increase the ability to predict outcomes, and enhance management/monitoring	- Provide support and training to local entities by the backbone organization - Organize regional workshops and learning networks for better training - Support integrating climate change aspects in reach scale plans - Promote the Sustained Funding concept to provide funding for planning
3	Policy Reinforcement	Harmonize the regulatory/policy tools (e.g., permitting process or comprehensive flood hazard management plans) with IFM	- Develop floodplains planning guidance and grant application guidance - Collaborate with projects sponsors to prepare better project proposals - Establish a dedicated permit assistance team from different involved entities to build a body of knowledge and manage the permitting process. A list of works needs to be permitted, a list of required permits, a description of permits and their objectives, and proper examples of applications should be provided. - Seek and implement potential changes to improve permitting process, flood control plans, and policies through cross-agency efforts. Such as streamlining the local, regional, and federal processes for permitting
4	Sustained Funding	Provide sufficient and diverse financial resources on time	- Administer various grant programs, simplify granting process, and increase state capital budgets for the projects - Seek/develop a wide range of funding systems (e.g., donation, local fees, federal grants, etc.) to support projects, monitoring systems, and backbone organization. Also, provide dedicated funding for regional planning - Establish grant coordination groups from all entities and develop a suitable user guide to floodplain grants - Work with Authorizing Institutions to better leverage federal funding, aligned with IFM purposes - Levy taxes (e.g., property tax) and develop regulatory incentives (e.g., fast permitting) for IFM projects
5	Driving Public & Private Markets	Build demand so that more of the public resources go to IFM	- Document the cost-efficiency of IFM addressing multi stakeholders' values - Document avoided costs by practising IFM - Track social and system change metrics and build the economic case for IFM

It should be mentioned that salmon recovery has been one of the main concerns of decision-makers in Puget Sound, as each major watershed established a local organization, called Lead Entity, to coordinate salmon recovery plans. In particular, the restoration and recovery strategies include enhancement/protection of connectivity between streams, rivers, and floodplains; restoration of hydrologic and sediment processes; and improvement of edge and off-channel habitats (TNC, 2014).

A vibrant community objective can be practised through various strategies to promote the regional quality of life, such as providing better recreational opportunities and greenways. A successful collaboration between local, state, and federal agencies as well as political authorities can accelerate IFM advancement, promote indigenous rights, and provide sustained funding resources for IFM implementation (Ecology, 2021; TNC, 2016).

3.5. An example of FbD implementation in the Puyallup Watershed

Puyallup River forms one of the major floodplain watersheds in Puget Sounds. This river has two main tributaries of the White and Carbon Rivers, flowing through numerous agricultural lands and small cities within Pierce County. Despite extensive dike construction over the past decades, flood damage remained one of the area's biggest challenges. In response, Pierce Country has shifted from the conventional mitigative approaches to risk-based, integrated floodplain management. One of the key productive IFM strategies in this watershed was to provide more room for the river through several dike setback projects, improving flood storage capacity and fish and wildlife habitats (TNC, 2018b).

Supported by the FbD grant, a considerable number of stakeholders and affected communities (i.e., representatives from indigenous communities, municipalities, agricultural and fishery associations, Pierce Conservation district, and their Lead Entity) have frequently been gathering to develop and advance the local IFM objectives within this area. Pierce County was the first County to hire a full-time coordinator to implement IFM using the FbD grant (Floodplains by Design, 2016; TNC, 2018b). They defined flood reduction, salmon recovery, and agricultural objectives as well as corresponding measurable performance metrics to enhance floodplain resilience in the area. They also characterized five reaches within this watershed while identifying "Significantly Modify" as the main floodplain management strategy. Subsequently, reach-scale objectives were defined by increasing specificity in the previous objectives, leading to a certain set of projects to advance IFM within the five reaches (Floodplains by Design, 2016; TNC, 2016).

In this watershed, it was estimated that a short-term investment of US$48 million [CA$61.44 million] would cover 76,000 feet of dike setback projects; 36,000 feet of inappropriate flood control structure removal; more than 1,100 acres of floodplain and river connection enhancement; 300 acres of side-channel habitat reconnection; and 400 acres of conservation easements for agricultural lands. These projects are intended to significantly reduce flood risks along the Puyallup and White rivers while enhancing fish and wildlife habitats in the area. As mentioned, the Calistoga Levee Setback project was one of the most successful projects implemented in the area. Various funding resources of US$8.3 million [CA$10.62 million], US$3 million [CA$3.84 million], and US$12.5 million [CA$16 million] were respectively allocated to this project from state, federal, and local financial sources, among which US$4.7 million [CA$6.02 million] was provided by the FbD grant. This project substantially protected the City of Orting against expected future floodings, reconnected more than 42 acres of floodplain, and enhanced salmon's migratory passage and vegetation pattern in the area (TNC, 2014).

Moreover, a monitoring and management program called "Floodplains for the Future (FFTF)" was implemented in this watershed to track watershed-scale advancements towards local IFM objectives. The collaboration through the FFTF program also followed the same cyclic pattern, illustrated in Fig. 3. Available funding allowed FFTF to simultaneously manage 44 projects in the area, including different multiple- and single-benefit projects for flood risk management, salmon recovery, and agriculture enhancement. FFTF monitored and managed these projects to achieve a better level of integration and sustain trust among stakeholders to fulfil a broader range of interests over time. The generated momentum of the FFTF collaboration provided agricultural associations with US$7 million [CA$8.96 million] of additional federal resources to secure conservation easements on agricultural lands. However, engaging many stakeholders with disparate levels of information and technical capacity to support their own interests was one of the main challenges of FFTF implementation. Joining new stakeholders caused the FFTF group to go back to earlier IFM steps redefining the vision, objectives, and required actions to accommodate the interests of more entities (TNC, 2018b).

3.6. Reddington Levee Setback project

3.6.1. Background

The "Reddington Levee Setback" project is part of an integrated flood management approach for the lower Green River in the City of Auburn, King County, Washington State. This was a multi-benefit project to enhance flood storage capacity and fish habitat in the area. Fig. 4 depicts the location of the project from the river mile (RM) 29.5 at 26th Street Northeast (the project's upstream) to RM 28.2 near the southern boundary of the Port of Seattle's wetland (the project's downstream). The 2006 Flood Hazard Management Plan of King County identified a series of issues in this area, including improper river connectivity, considerable risk of flood and malfunction of dike's hydraulic structures, steep slope angles of the dike with poor vegetation, and lack of sufficient set back from the river in most parts of the dike. This plan suggested dike removal and replacement with a setback dike to reconnect the former side-channel habitat into the river (King County's DNRP, 2007).

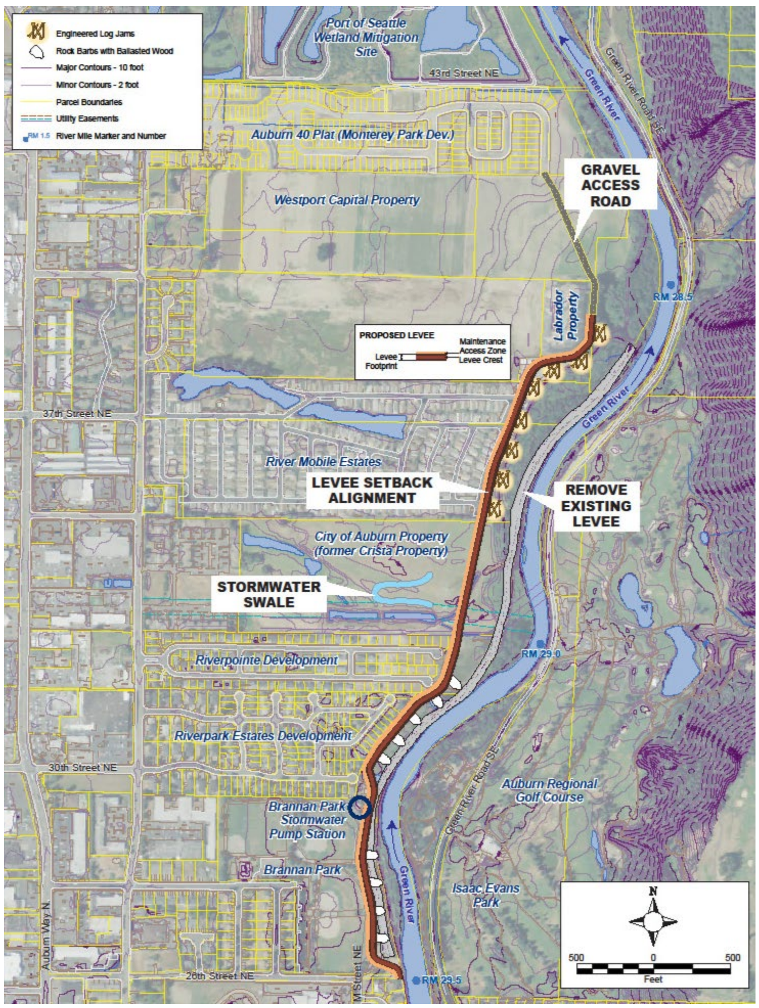


Fig. 4. Reddington Levee Setback study area (McCarthy et al., 2013)
Source: Habitat monitoring plan prepared by the King County Department of Natural Resources and Parks

The King County flood district demolished the previous dike (i.e., the one constructed near the edge of the river) and replaced it with a 1.3-mile setback dike in 2013-2014 (King County, 2021).

This project perfectly aligned with the salmon habitat recovery plan for the Green River basin to protect endangered salmon species in the area (WRIA 9, 2005, 2021). King County and the City of Auburn collaborated to implement the project to solve a major flood issue that affected the area's residents for decades (King County, 2021).

3.6.2. The project's goals, objectives, and actions

Habitat restoration by improving Green River's natural connections while reducing flood risk to the area were the project's main goals within the mentioned reach. The following associated objectives were considered to achieve the goals of the project (King County, 2021; McCarthy et al., 2014):

- allowing river expansion by setting the dike back to form better instream and riparian habitats (i.e., with slower water velocities) and increase the dike's flood storage capacity;
- placing large wood to improve the rearing habitat of juvenile salmon; and
- protecting and enhancing native vegetation to create an improved, nutritious fish and wildlife habitat.

The dike's previously existing system, constructed during the 1960s, was designed to withstand approximately a 100-year flood. Near US$ 17 million [CA$21.76 million] were spent for the entire Reddington Levee Setback project to proactively protect over 6,000 residents of the area against a 500-year flood while significantly enhancing the ecosystem (King County, 2021).

To implement the project, approximately 0.9 miles of the previously existing dike were removed and replaced with a well-designed setback dike. A total number of nine buried rock barbs were constructed on the dike's river channel side between RMs 29-29.5 to protect the toe of the setback dike against erosion and accelerate riparian forest formation. A total of 122 pieces of large wood and 54 pieces of racking wood were installed between the buried rock barbs, and three shallow alcoves were also excavated between some of the barbs to create better salmon habitat. Additionally, eight engineered log jams were constructed with 224 pieces of wood between RMs 28.5 to 29 to roughen the river's edge and form a side-channel rearing salmon habitat (the wetland) in the northern parts. Approximately 14,000 trees, shrubs, and willow stakes were planted over both riverbanks to create a 19-acre buffer zone. Several residential lands were acquired and demolished to increase the flood storage capacity of the setback dike (McCarthy et al., 2014).

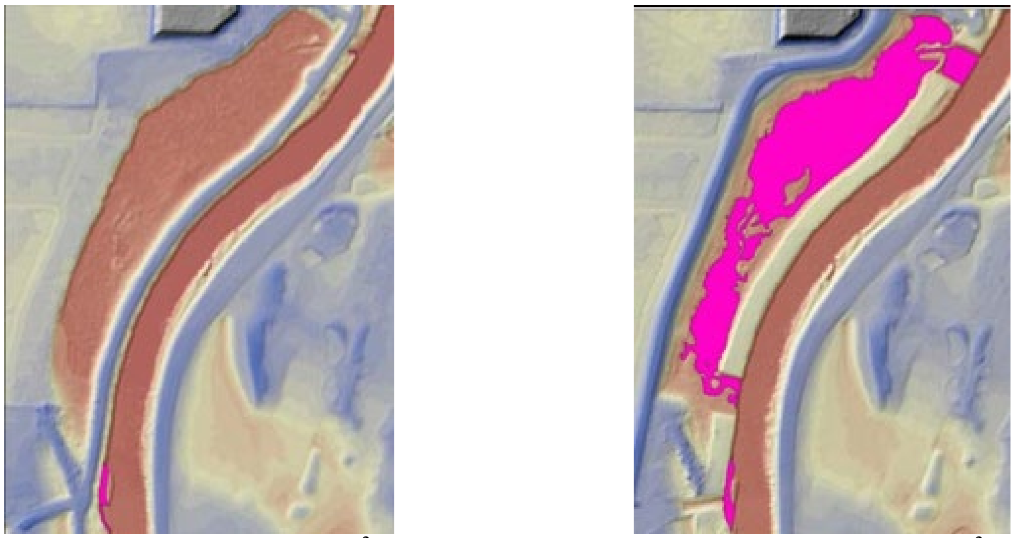
3.6.3. The project's outcomes

Various parameters were measured before and after the dike setback to assess the project's progress towards the defined goals and objectives. To this end, the river's bathymetry and extension of the wetlands and slow-water edge habitat were evaluated. Several parameters, such as vegetation conditions, were just monitored after the project implementation due to the lack of information before restoration. Effects of environmental variability were also assessed through a fish sampling program after the project. In this direction, the following major items were monitored (McCarthy et al., 2014):

- the site general condition (e.g., overall vegetation pattern and any structural damages)
- extension and types of low-velocity edge habitat (i.e., with water velocity <0.45 m/s)
- the side channel (i.e., the wetland) connections by photographing its inlet and outlet
- stability of installed log structures near the setback dike
- the survival rate of installed plants within randomly established monitoring transects
- native and invasive vegetation cover (i.e., per cent cover in planting areas)
- species, fork length, and weight of fish within Reddington, control and reference sites

Evaluating the general site condition led to the identification of priority weed removal areas. After setting the dike back, the rate of increase in the area of the low-velocity edge habitat regarding a corresponding discharge increase was significantly larger than the initial rate before the project. Prior to restoration, the values of the low-velocity edge habitat area were 5462 ft^2 and 11368.5 ft^2 at 1330 ft^3/s and 3060 ft^3/s discharge, respectively. After restoration, the area's values increased to 19860 ft^2, 168547 ft^2, and 228617 ft^2 at 1300 ft^3/s, 2060 ft^3/s, and 3360 ft^3/s discharge, respectively. Fig. 5 compares extensions of the low-velocity edge habitat at two close discharges in the downstream parts of the project's reach. The observed increase in the area is likely due to more availability of open floodplains for inundation in the absence of the river-edge dike (McCarthy et al., 2014).

While the inlet (i.e., upstream) of the wetland was connected to the river in case of flow discharges equal/greater than 2,410 ft^3/s, its outlet (i.e., downstream) was fully connected with flow discharges equal/greater than 1,420 ft^3/s. Hence, the wetland's inlet and the river were connected 29% of the time from 1st of January to 30th of June after restoration, and the wetland's outlet was connected to the river 70% of the same period. Based on the findings of the progress monitoring, a trench with a depth of one foot was excavated to introduce more water into the inlet of the wetland, forming a better salmon rearing habitat. While installed log structures remained desirably stable, numerous additional woods were placed for further reduction in water velocity (McCarthy et al., 2014).



a. before restoration at 3060 ft^3/s b. after restoration at 3360 ft^3/s

Fig 5. Extensions of the low-velocity edge habitat (the pink area) at the lower project region (McCarthy et al., 2014)

Source: A monitoring report prepared by the King County Department of Natural Resources and Parks

The plant survival in 11 planting areas varied from 57.9% to 88.6% of the initial plants number, in which six areas fulfilled the regulatory requirement by more than 80% plant survival, and five were less than this threshold. These discrepancies were likely related to variation in soil compaction and elevation of the areas, affecting water availability. Following the plant survival monitoring (i.e., a year after the initial planting), all areas were replanted to 100% of the initial condition to enhance the vegetation pattern. The native vegetation covers varied from 8% to 18.2% and the invasive covers were in the range of 0.3% to 31.5%. The native vegetation covers were completely satisfactory in two planting areas. Proper maintenance and timely watering can enhance the vegetation pattern and survival. Also, it seems necessary to modify and prepare the planting site for soil compaction enhancement and additional watering treatments prior to planting vegetation. Repetitive weed treatments may also reduce covers of invasive plants, causing better survival and growth rates for native species (McCarthy et al., 2014).

Within the fish sampling process, 167 fish from 11 species were collected from four locations across the Reddington site (i.e., the project's site). Among them were four different juvenile salmon species, including Chinook, Coho, Chum, and Pink (in order of abundance). Sampling was also performed on different control and reference sites due to the lack of the relevant information in the

Reddington site prior to restoration. Statistical evaluation of the results indicated that Chinook abundance was higher within the Reddington site than in the control and reference sites, while their difference is statistically significant. The fork length and weight comparisons indicated no significant difference between Reddington, control, and reference sites for Chinook's mean length and growth rate. It should be mentioned that several sources of bias were also reported for the sampling process that might affect fish abundance and size estimations within this monitoring system (McCarthy et al., 2014).

Overall, the setback dike project effectively achieved the goals and objectives defined under this case study. For example, the area of low-velocity edge habitat was significantly increased after the project implementation compared to the pre-restoration condition. Approximately 1911% post-restoration increase in low-velocity edge habitat was achieved at discharges of 3060 ft^3/s for pre-restoration and 3360 ft^3/s for post-restoration. However, a complication occurred within the wetland's inlet, which was one foot higher than the elevation considered during the design process. As mentioned, the problem was ameliorated by excavating the one-foot-depth trench better connecting the wetland to the river. This way, the wetland provided Chinook salmon with a suitable rearing habitat.

3.7. Fisher Slough Tidal Marsh Restoration project

3.7.1. Background

This case study was a multi-benefit ecosystem restoration project to enhance agricultural lands, fish habitat, and flood control conditions in private lands within the South Fork Skagit River Delta in the northern Puget Sound. The Fisher Slough project (Fig. 6) aimed to restore a 60-acre tidal marsh at the southern boundary of the Town of Conway, Skagit County, Washington State, receiving runoff from 14,720 acres of land. Like many other areas in the Puget Sound region, farming and salmon harvesting shaped the economy's foundation in this area, while there has been a historical conflict between fish advocates and farmers. The legacy of expanding active agricultural lands through extensive floodplains' diking and draining caused a more than 65% reduction in the number of Chinook compared to the early 1900s in Puget Sound[9]. This number is even worse with up to 80% reduction within the Skagit River delta - the source of half of the wild Chinook in the Puget Sound region. Subsequently, enhancing Chinook's migratory and rearing habitats has been a primary issue for numerous governmental agencies, non-governmental

[9]Chinook have been listed as threatened in the area under the US Endangered Species Act since 1999 (Baker, 2013).

organizations, and indigenous communities in the study area. Alternatively, maintaining the function and production level of farmlands as well as protecting the adjacent lands against flood risk (increased by river-edge diking) have also been other equally important priorities (Tetra Tech, 2009; TNC, 2017).

This project was an example of the actions that can build trust among stakeholders with historical conflicts and generate the required IFM momentum. Several elements of effective local IFM can be discerned through this case study, such as extensive stakeholder engagement, building trust through the shared vision, securing sustained financial resources, adaptive management of the project, and establishment of an effective monitoring system. Having a restoration project within privately-owned lands is another significance of this case study as the previous projects in the area were almost implemented in public lands, comprising only a small portion of the suitable lands for habitat restoration (TNC, 2017).

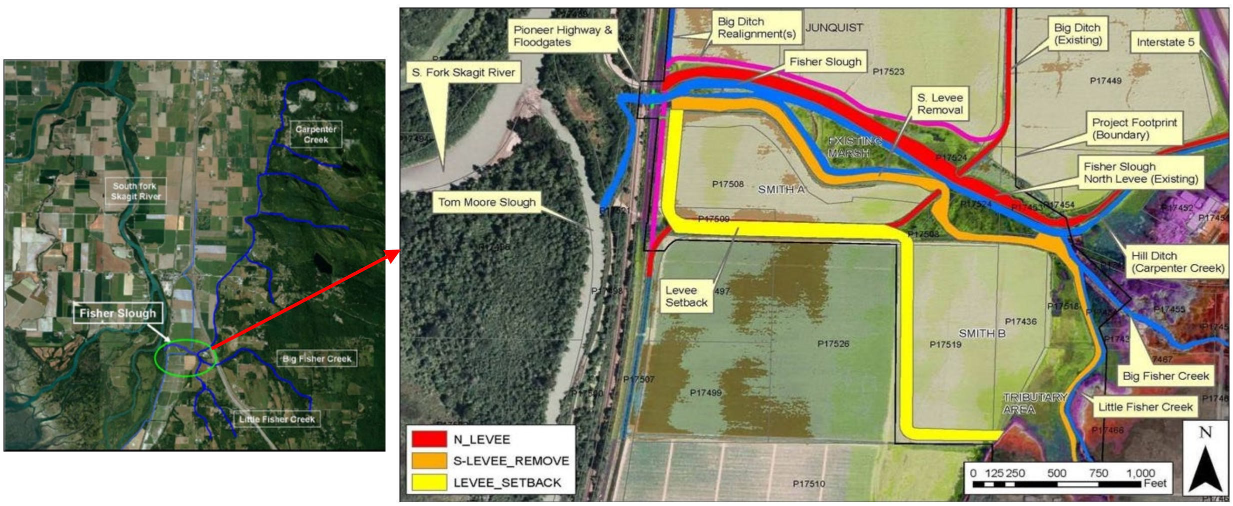


Fig. 6. The Fisher Slough's area of restoration (Baker, 2013; Tetra Tech, 2009)
Source: Project's final report and Final basis of design report

3.7.2. The project's goals, objectives, and actions

Several equally weighted goals of Chinook habitat and ecosystem restoration, agricultural land protection, and flood risk reduction by increasing storage capacity were considered in this project. As depicted in Fig. 6, the project includes the following major components (Baker, 2013; Tetra Tech, 2009; TNC, 2017):

- Replacement of the single-hinge floodgate, blocking fish passage and tidal exchange.
- Realignment of Big Dich and elimination of associated culverts, limiting the area for dike setback and blocking fish passage.

- Restoration of marshlands by setting back the dike, limiting the floodplain's area to 10 acres while the floodgate is closed and disconnecting the river and ecosystem.

The components aimed to restore the tidal marsh; enhance the river, floodplain, and estuary connectivity (i.e., reconnecting fluvial and tidal processes); increase flood storage capacity; and reduce riverbank and dike erosion. These objectives were considered to improve the native vegetation diversity, Coho and Chum migratory passage, Chinook rearing habitat, and birds' migratory habitat while protecting the agricultural lands against a growing flood risk (Baker, 2013; Tetra Tech, 2009).

To have effective coordination and knowledge transfer between involved entities during the design process, TNC assembled a Technical Advisory Committee with 17 members from representatives of fish and agricultural associations, permitting agencies, and sponsors. The natural resources consortium of the Swinomish and Sauk-Suiattle tribes was a member of this committee. TNC provided this committee with regular updates and used their technical capacity and feedback to address design issues (Baker, 2013). TNC also acquired the primary land[10] to implement the project's components in close collaboration with Skagit County's Dike District 3, Drainage and Irrigation District 17, and indigenous communities. Seven other landowners of the adjacent areas were also involved in the project. To conduct adaptive project management, TNC established a monitoring and adaptive management plan through collaboration with the involved entities. This plan included pre- and post-project monitoring from 2009 to 2015, while the project construction started in the late 2009 and was completed in 2011 (Baker, 2013; TNC, 2017). A comprehensive description of the project's components, design and construction procedures, relevant permitting information, and sequence of the project implementation was provided in a design report document prepared for TNC by Tetra Tech Engineering Consultant prior to starting the project (Tetra Tech, 2009).

3.7.3. The project's outcomes

The project was financially supported by the American Recovery and Reinvestment Act funding and the Estuary Habitat Restoration Program grant from the US National Oceanic and Atmospheric Administration (Baker, 2013). Over eight years, the project led to US$8 million [CA$10.24 million] economic benefit for the Puget Sound region by creating about 300 job opportunities through 47,000 labour hours. The long-term benefit of the project has been estimated between

[10]The land in which setback dike was built and a major part in which tidal marsh was restored (Baker, 2013).

US$9.1 - US$20 million [CA$11.65 – CA$25.6 million] over a 50-yr period, significantly exceeding the project's total cost (i.e., US$7.7 million [CA$9.86 million]). The project reduced flood damages, increased agricultural production and reliability, and decreased associated maintenance and operational costs of the previous ageing infrastructures. In addition to fish habitat and ecosystem benefits, the trust forged among the local entities also facilitated addressing other issues in the community (ECONorthwest, 2012; TNC, 2017).

Particularly, each component of the project led to multiple benefits for the study area. As the initial step in implementing the project, the floodgate replacement considerably improved the hydrological connectivity while maintaining the flood protection level. The old barn-style gates of the previous structure were replaced with side-mounted gates through new self-regulating floodgates. This new hydraulic structure automatically operates the side-mounted gates using a system of arms and an upstream float based on the upstream water elevation and a predefined float setting. The arms keep the gates open in lower water elevations than the float setting. In contrarily, the arms retract to put the gates into a free-swinging condition when water elevation rises above the float setting. It is also possible to keep the gates in the free-swinging condition at all water elevations by disengaging the float (Beamer & Henderson, 2016). The floodgate replacement enhanced the fish acceptability to slough for rearing and spawning through 15 miles of tributary habitat and improved water quality by increasing tidal exchange. The new floodgate stays open two times more than the previous one while remaining open more than 90% of the time during the salmon's spring migration. The new floodgate also provided Coho and Chum access to 15 miles of tributary habitat during the fall and winter months to return to spawn (Beamer & Henderson, 2016; TNC, 2017).

Relocation of drainage infrastructure, including a 4,100 ft-long realignment of Big Ditch, removed fish blockades and rehabilitated the old irrigation systems. The local water temperature was also decreased through the ditch realignment due to the elimination of local ponding effects. While the previous culvert of the ditch had the capacity to safely convey a 25-yr flood event, the new system can route a 100-year flood. It is a submerged system to provide an enhanced fish passage at a wider range of flow regimes. As mentioned, the relocation also provided sufficient space for the dike setback construction by consolidating the drainage infrastructure on the west side of the study area (Tetra Tech, 2009; TNC, 2017).

Replacing the previous 12 ft-height dike with a new setback dike with the same elevation, restored 56 acres of tidal marsh and reduced riverbank/dike erosion through the 4500 ft alignment length of the dike. Additionally, the setback dike construction increased the flood storage capacity of the adjacent lands by 245 acre-feet (i.e., slough enlargement) which is approximately five times larger than before restoration. This additional capacity was enough to contain a five-year tributary event in the area. The area experienced a costly five-year tributary flood prior to the project implementation. On the contrary, the new system successfully contained a ten-year tributary event that occurred after restoration and surpassed the initial expectations (TNC, 2017). Setting the dike back also caused an enhancement in the native vegetation pattern after planting 9,555 trees and shrubs within the restored area. It also eliminated the need for river dredging by improving the sedimentation process. The vegetation pattern has been evolving since the project's implementation while it started shaping a freshwater wetland ecosystem two years after restoration (Baker, 2013; TNC, 2017). In parallel, the dike setback considerably increased spatial variability in water temperature as one of the main factors affecting fish metabolize productivity. The growth rate of the juvenile salmon increased after restoration due to their enhanced access to cool water feeding areas and better rearing ponds. The mean fork length of juvenile salmon increased by 5.2 mm compared to an identical period before restoration. The growth rate enhancement was more prevalent within spring and early summer. Also, 22,000 additional Chinook salmon were produced annually in the restored area (Beamer et al., 2017).

Overall, the evaluation of the project outcomes from 2009 to 2015 indicated that the expected goals and objectives of the project were all met or even exceeded. This success is rooted in developing and implementing a multi-benefit project that addresses a broader range of interests through close collaboration with various influential partners. However, this was a complex restoration project that required effective risk management. This project's experiences indicated that the risk of delays and costly alterations could be reduced by detailed upfront investigations within the feasibility study and design phase. A clear understanding of permitting processes is needed within the upfront investigations in addition to site-specific data acquisition. The construction process should also be continuously monitored until the project's completion. The project's liabilities are another important aspect of this complex restoration that requires technical consultation with experts to be addressed through contracts, agreements, bonding, insurance, and so on (TNC, 2017).

4. Yuba Watershed Case Study

4.1. Introduction

The Yuba watershed case study is an appropriate example of successful collaborations between multiple entities to discover ecosystem-friendly solutions to flood risk while seeking economic, ecological, and public safety benefits. Flood risk reduction, agriculture growth, and improvement of anadromous fish habitats are the key components of IFM through this case study. The diversity within the communities of the study area is also significant. In addition to a major community of Caucasians, First Nation, Hispanic/Latino, and Hmong communities are the minority ethnic groups (Yuba County RWMG, 2018). Addressing the environmental justice issues was in great demand concerning this substantial level of diversity. The communities in this area had distinct levels in terms of development and economic conditions. The potential impacts and benefits of management plans on vulnerable and minority communities and properly engaging them in planning and implementation processes were essential factors considered in this case study.

Plans reviewed within the Yuba watershed case study approximately cover 632,000 acres situated in the central valley of California, US. The area extends from the Sierra Nevada foothills to the Sacramento River near Golden State Highway and includes portions of different counties: Yuba, Butte, Sutter, and a small part of Placer (California DWR, 2014; Yuba County RWMG, 2018). While agricultural activities lay the economic foundation of the area with the most prevalent land use, urbanization has been recently growing. For example, the Yuba County population is expected to nearly double by 2050 relative to 2010, with 72,155 residents (Yuba County RWMG, 2018). Agricultural and urbanized lands expanded around three main rivers in this area, including Feather, Yuba, and Bear Rivers, by constructing extensive systems of dikes for flood protection over the past 160 years. Other components of the flood management system are upstream reservoirs to reduce flood peaks and pump stations to discharge water from protected areas back into flood control channels. Yuba and Feather Rivers offer profitable opportunities for water-based recreational activities to enhance the residents' quality of life and local economy. The ecosystem of the area also provides valuable habitats for anadromous fish with dominant species of Chinook salmon. However, the presence of extensive diking, dams and impoundments, and degenerated streams adversely impacted the salmon population due to fish passage blockage, floodplain depletion (for rearing), water temperature increase, water quality deterioration, and natural flow rate reduction.

Despite the use of the flood management system mentioned above, the area frequently experienced substantial flood incidents, particularly riverine and flash flooding. Two significant flood events happened in February 1986 and January 1997, with US$450 and US$150 million [CA$576 and CA$192 million] of the total damage, respectively. The latter inundated 1,600 acres, causing three losses of life and the evacuation of 38,000 residents. This area also experienced more recent severe floods in the 2005 and 2006 winters, with widespread damage across Yuba County (California DWR, 2014; Yuba County RWMG, 2018). Having a long-term history of significant flood events, flood management is identified as one of the major issues in the area. This is mostly due to insufficient capacity and inadequate construction quality of dikes, considering the growing severe, climate change-induced storms during winters (Yuba County RWMG, 2018). The required structural and operational improvements on dikes and reservoirs; degradation of fisheries and wildlife habitats; and high flood insurance rates relevant to new dike standards - defined by FEMA[11] through a nationwide flood re-mapping project - are the major flood management challenges. The reliability of water resources is also a matter of concern in this area, relying on surface water and groundwater sources as the main water supplies in urban and rural areas, respectively. The plans attempt to consider both surface water and groundwater as a single resource to attain effective water resource management (Yuba County RWMG, 2018). To address water-related issues, the following non-structural measures were recently considered in the area to some extent (California DWR, 2014):

- raising and waterproofing structures
- purchasing and relocating at-risk structures
- limiting development in floodplains through the acquisition of agricultural and habitat conservation easements
- establishing open space easements, flood regulatory constraints, and incentive programs
- initiating floodplain restoration projects

Two main documents reviewed within this case study include Feather River Regional Flood Management Plan 2014 (RFMP) and Yuba County Integrated Regional Water Management Plan 2018 (IRWMP), each covering a portion of the studied area while having some degree of overlapping. Whilst the former attempts to establish all sustainable water management aspects in

[11] The Federal Emergency Management Agency

its study area within a 20-year horizon timespan, the latter defines flood management priorities, funding mechanisms, and specific projects to reduce flood risk in the Feather River region. A wide range of institutes and agencies collaborated to prepare these documents in addition to indigenous communities, non-governmental organizations, and public representatives. The major institutes and agencies were the California Department of Water Resources, Yuba County IRWM Regional Water Management Group (RWMG), Yuba County Water Agency (YCWA), Three Rivers Levee Improvement Authority, Marysville Levee Commission, and Sutter Butte Flood Control Agency. YCWA and Three Rivers Levee Improvement Authority were extensively involved in developing and implementing both documents. A summary of RFMP was incorporated within IRWMP as a flood management chapter. The present review is also structured based on IRWMP (the plan) as a more recent document explicitly incorporated IFM while including valuable suggestions and experiences of RFMP within this structure. The IRWMP area is depicted in Fig. 7.

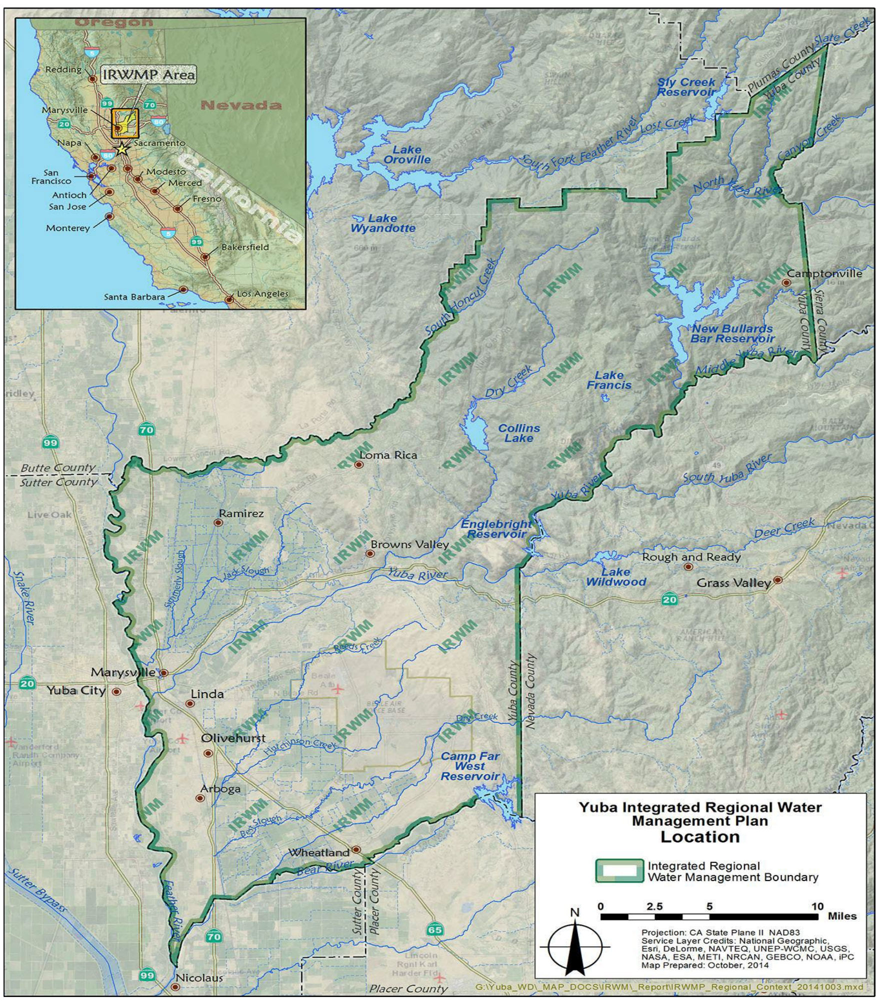


Fig. 7. The study area of IRWMP (Yuba County RWMG, 2018)
Source: [Yuba County IRWM Regional Water Management Group]

A combination of structural and non-structural strategies was suggested in these plans to reduce flood risk as part of the multi-objective projects. Apart from flood risk management, these projects aim to integrate agricultural land preservation with fisheries and wildlife habitat restoration through multi-stakeholder collaborative activities (California DWR, 2014; Yuba County RWMG, 2018).

4.2. Development process, visions, and objectives

Visions, objectives, and strategies considered in the reviewed documents in this studied area were developed according to an extensive phased-based outreach to all influential stakeholders. The stakeholder's long-term engagement was performed through in-person visits, an outreach system of phone calls and emails, designing and developing a website to collect and disseminate information, and scheduled public meetings, gatherings, and workshops. One of the most successful approaches to initially involve stakeholders was travelling to meet representatives of associations and organizations due to their limited staffing and travel budgets. Vulnerable and minority communities were also the key focus of the outreach process. A wide range of concerns and comments were addressed through revisions of draft documents based on stakeholders' feedback, especially from fisheries and agricultural associations (California DWR, 2014; Yuba County RWMG, 2018).

Within the IRWMP development process, 81 stakeholders were approached twice in person and once by phone and email. To effectively coordinate between all stakeholders, drafts of projects defined under the plan were sent to stakeholders and made publicly available through the website. This action facilitated the collaboration between stakeholders to address potential conflicts and synergies between individual projects. Indigenous communities were recognized as sovereign nations requiring government-to-government basis coordination. Therefore, YCWA officially sent certified letters inviting them to the development and implementation processes of the plan and projects. Also, outcomes of the Disadvantaged Community Involvement (DACI) Program were practised, facilitating a coordinated outreach to indigenous communities. DACI was a three-year program aiming to effectively identify and resolve obstructive factors to engage vulnerable and indigenous communities in decision-making.

Additionally, all relevant information and materials were placed in local libraries of rural communities to improve public availability in the areas with limited online access. Local groups, individuals (through an on-street outreach), and leaders of Latino/Hispanic and Hmong communities were also sufficiently involved. To this end, informative brochures were prepared in Spanish and translators were employed for better interaction with the Latino/Hispanic community. After this extensive outreach process in IRWMP, the interviewed stakeholders were furtherly engaged in future conventions to decide on grants applications and projects' advancement funds. A specific voting system was also designed to reach a consensus within these larger meetings. Through this system, all entities adopting the current version of the plan had a single vote, and a decision was only made by consensus in a present meeting or by a 75% supermajority vote in a subsequent meeting. However, to be able to cast a vote in the subsequent meeting, an entity must have at least participated in two out of the last three meetings (Yuba County RWMG, 2018).

IRWMP defined seven goals, including:

- "*ensure adequate and reliable water supply that meets the diverse needs of the region;*
- *protect, restore, and enhance water quality for water users and in support of healthy watersheds;*
- *preserve and restore watershed health and promote environmental stewardship;*
- *enhance regional economic development by supporting recreational opportunities and sustainable agriculture;*
- *protect public safety through emergency and drought preparedness and integrated flood management; address climate vulnerabilities and reduce greenhouse gas emissions; and*
- *promote equitable distribution of resources to disadvantaged communities and Tribes across the region.*"

Multiple corresponding, measurable objectives with the same priority level were considered under each goal to promote integrated management practices more effectively. Some of the synthesized objectives which are more relevant to the scope of the present review and their measurable performance metrics have been tabulated in Table 2. The goals and objectives of IRWMP are consistent with both state-wide plans, policies, and regulations and local and regional ones, such as RFMP. One of the main aligned aspects is to promote and practice IFM to attain multiple benefits simultaneously. Various water, watershed, and land-use planning documents were also reviewed in the preparation of the IRWMP's updates to avoid potential conflicts. Some of these reviewed documents are as follows (Yuba County RWMG, 2018):

- urban water and groundwater management plans
- Lower Yuba River Accord

- recovery plans for the Sacramento River winter-run Chinook salmon, the Central Valley spring-run Chinook salmon, and the California Central Valley steelhead

Likewise, the main goal of the RFMP is to improve flood risk management while reducing operational costs through nature-based strategies; promoting ecosystem functions; and practising multi-benefit projects within a collaborative system. Different structural and non-structural strategies were suggested through multi-objective projects of this regional plan to preliminary preserve agricultural lands while enhancing fish and wildlife habitats (California DWR, 2014). Increasing public recreational opportunities and river corridor access were also considered in RFMP as a secondary objective in a way that does not compromise flood control and agricultural facilities/activities. While long-term maintenance and management costs of water-based recreational projects should be minimized, a wide range of agriculture, habitat conservation, and water supply values must also benefit from these projects. Thus, recreational opportunities could be explored within other types of projects explained in the following sections, such as dike construction/setback, fish passage construction, and easement implementation (California DWR, 2014).

Table 2. Several objectives and their corresponding performance metrics within the Yuba Watershed

No.	Objective	Performance metrics
1	Water quality improvement and habitat restoration to protect fisheries and species with economic, ecological, and cultural values	- Length of stream protected or restored - Areas of riparian habitat and/or floodplain protected, restored, or created - Annual mass of pollution reduced - Number of implemented best management practices - Frequency of sampling and monitoring
2	Function enhancement of floodplain and wildlife habitat while achieving multiple benefits and public safety	- Amount of groundwater recharged - Number of implemented projects - Miles of stream protected or restored - Acres of riparian habitat and/or floodplain protected, restored, or created - Amount of the carbon sequestration
3	Establishment of recreational river corridor linkage while improving migration corridors for plants and animals	- Length of rivers improved - Number of developed and implemented projects
4	Providing vulnerable and indigenous communities with necessary assistance, training and education, and the capacity to prepare proposals and grant applications for projects and manage their own recreational amenities	- Number and diversity of people reached - Number of training conducted, projects implemented, and assessments performed - Number and diversity of outreach materials developed - Number of engaged communities of interest

4.3. Climate change considerations

A comprehensive evaluation of climate change effects was performed in the area to identify and prioritize climate change relevant vulnerabilities. Following that, corresponding existing adaptive strategies were evaluated and potential future strategies were introduced to enhance climate resilience.

Climate change increases the intensity and frequency of severe storms that negatively impact flood control structures' performance to accommodate excess runoff. Alternatively, it may also lead to water deficits in the area, jeopardizing both agricultural activities and aquatic species life. Considering the interrelated natures of climate change and IFM, practising the plan's objectives, strategies, and projects in this area will also improve regional climate change adaptation over time. These items will also be revised based on new upcoming data and studies about the localized effects of climate change. Major adaptive strategies to climate change considered in this plan are as follows:

- Upgrade and setback dikes
- Provide off-channel salmon habitat
- Restore headwaters meadow and fish and wildlife habitats
- Remove several dams
- Practice GHG reduction considerations (i.e., implementing GHG-efficient development patterns in the projects)[12]

These strategies not only improve climate change resilience in the area, but also reduce risks of flooding, wildfire, drought, and other climatic disasters (California DWR, 2014; Yuba County RWMG, 2018).

4.4. Financing strategies and implementation

4.4.1. Financing

Two different types of funding systems were considered: program funding to support administrative aspects of planning (e.g., plan development, outreach process, plan update, and progress monitoring) and project funding to implement specific projects approved under the developed plan.

[12]Mitigative strategies for GHG emission reduction were also mandatory to be submitted through the application process of each proposed project under the plan.

Each partner adopting IRWMP was committed to providing the required program funding. Hence, key financial resources for program funding were secured from the investments of various RWMG partners through donations and administrative line items defined under project grants. Additional sources of support for the program funding were the foundation and public grants. The required investments in project funding are significantly more than program funding and should be secured from public and private grants, user fees, and in-kind donations. The potential sources of project funding are revenue bonds, property tax assessments, user fees, special districts (i.e., voluntary groups of a community), State grant sources, federal funding, and a variety of private foundations. It is worth mentioning that California's Flood Future (and associated Attachment I: Finance Strategies) thoroughly explains available funding systems to improve flood management preparedness in this state. Various funding and financing mechanisms available to local entities for flood management in California are also listed in that report (California DWR & USACE, 2013).

4.4.2. Implementation

As part of the plan implementation actions, frequent meetings were held to monitor the plan's progress based on performance metrics, sustain project funding from diverse sources, and update the plan based on new guidelines and projects' outcomes. The plan evaluations were also published annually and were publicly available through the developed website, in which interim changes were mentioned. Formal revisions to the plan are also expected to occur every three to five years (Yuba County RWMG, 2018).

As part of project implementation actions, quantitative metrics of the projects' outcomes should be submitted into a standardized data management system by each project's sponsor, responsible for monitoring the respective project's progress. The data management system is available on the developed website administrated by RWMG. In addition to the initial call for projects proposal, projects can be proposed following various period calls to expand opportunities for considering more recent and capable IFM strategies. A project development workshop helped stakeholders to get familiar with the process. A project's application process requires the sponsors to clearly demonstrate the approach that the proposed project addresses a regional issue while being consistent with the goals and objectives of the plan. The project's inclusion was subject to various evaluation criteria such as multi-objective level of individual projects, resource management strategies (RMSs) considerations, and specific benefits to vulnerable and indigenous communities.

RMS is a policy, program, or project practised by local or regional authorities for water resources management, such as flood risk management and urban storm runoff management RMSs. All relevant and regionally applicable RMSs were determined for each objective (under each goal) of the plan. The application process must exhibit how each proposed project incorporates relevant RMSs (Yuba County RWMG, 2018).

Rather than ranking all proposed projects, RWMG attempts to incorporate as many projects as possible over time based on available funding opportunities with specific priorities. This approach avoids potential conflicts and unnecessary competition among involved proponents. In this direction, the proposed projects will be presented by corresponding sponsors to RWMG and undergone various evaluation criteria to confirm their consistency with the plan. Then, the group will vote (i.e., through the previously mentioned system) to whether approve the project's inclusion in the plan. In case of approval, the projects will be implemented based on a suitable, available budget opportunity (Yuba County RWMG, 2018).

4.5. Impacts and benefits of implementation

Like the funding system, two types of programmatic and project-level impacts can be identified that may hinder the implementation of the plan and projects, respectively. Impacts of the programmatic level implementation were mainly due to administrative and management expenses needed for organizing meetings and outreach activities, maintaining the developed website, updating the plan, and coordinating projects. At the project level, the cost and time required for project implementation were the main sources of impact, especially within vulnerable and indigenous communities with limited human and financial resources. Traffic and noise disruptions to local people during construction activities and temporary water and air quality deterioration can also be other project implementation impacts (Yuba County RWMG, 2018).

However, the benefits of the plan and projects implementations were already notable, and it seems they will continue to be beneficial to the area. Some of the major benefits at the programmatic level can be summarized as follows:

- reduction of flood-originated health issues
- enhancing the financial and technical capacity of vulnerable and indigenous communities
- improving collaboration and understanding between stakeholders
- developing integrated and cost-effective solutions to regional issues
- sustaining diverse funding resources for project investment

Furthermore, failure to implement the plan could be detrimental to the whole area, such as high flood costs and loss of at-risk species prone to low-flow rates of streams.

The main project-level benefits can be widespread such as:

- reduction of flood risks in the area, increasing public safety;
- restoring and protecting fish and wildlife habitats;
- strengthening the local economy;
- improving water-based recreational activities and tourism;
- enhancing both water quality and quantity; and
- reducing GHG emissions.

Implementing the plan and projects may considerably benefit vulnerable and indigenous communities by achieving a short-term employment rate increase and long-term solutions to water supply and public health (Yuba County RWMG, 2018).

4.6. Specific strategies to practising Integrated Floodplain Management

RFMP described specific strategies to preserve agricultural lands along flood corridors in a wildlife-friendly manner. This section provides a summary of these major strategies and management actions. The following strategies are suggested in the study area to restore and protect fish and wildlife habitats while preserving agricultural lands (California DWR, 2014):

- increasing floodplain transitory storage through setback dike projects and wildlife-friendly implementation of channel improvement strategies
- establishment of extensive conservation easements on agricultural lands and wildlife habitats
- enacting the Lower Yuba River Accord and incorporating its experiences

The Lower Yuba River Accord and the establishment of conservation easements are notable strategies concerning the integration of multiple purposes and collaboration between numerous entities. Although setback dike construction is briefly introduced in the following section, large-scale setback dike projects in King and Skagit Counties have been extensively evaluated in previous sections as two local projects of dike alternative solutions to floods.

4.6.1. Floodplain transitory storage and channel improvement

Floodplain transitory storage concept is one of the key strategies to expand the active floodplain by removing, setting back, and breaching a dike. However, this strategy has been controversial because of its potential to damage adjacent agricultural lands and properties. Nonetheless, a controlled inundation of these lands can considerably reduce flood pressure on dikes. Upgrading or building setback dikes is one of the significant aspects of IFM. It can be beneficial to human safety as well as the protection of urbanized and agricultural lands against climate change impacts. This strategy may also enhance river connectivity, reduce river channelizing, recharge groundwater, and provide nutrient habitats for aquatic species and rearing ponds for anadromous fish. The long-term benefits of this strategy to the ecosystem will exceed its initial significant costs. However, it should be implemented consistently with land-use plans and following an agreement with affected landowners. The agreement should compensate them for the loss of long-term agricultural productivity and immediate land values, as explained in the next section (i.e., Conservation easements). Dikes conditions could also be improved by a combination of practices, such as raising crown elevation; enhancing structural stability and seepage conditions; removing/improving penetrations; and planting native, perennial grasses over rehabilitated and new sections (California DWR, 2014).

In case of channel improvement strategies (e.g., channel grading/sediment removal and channel vegetation management), a multi-objective erosion protection approach should be deployed. An implementable multi-objective approach attempts to enhance fish and wildlife habitats through a profound understanding of fluvial processes' interactions with the natural environment. For example, channel dredging, conducted to increase a stream's navigation and conveyance capacity, requires significant excavation of a riverbed. This strategy is unlikely to be incorporated in multi-objective projects since it could be highly detrimental to aquatic species by resuspending toxic components, increasing water turbidity, and physically damaging their habitat (California DWR, 2014).

4.6.2. Conservation easements

The main purpose of this strategy is to maximize the use of floodplains as fish and wildlife habitats - which ultimately reduces flood risks - while minimizing the conversion of agricultural lands. Three major types of easements were suggested, including agricultural conservation, habitat conservation, and flowage easements. The former is a voluntary legal agreement banning practices that can interfere with agricultural productivity within the subject land. Such as unnecessary constructions reducing the footprint of actively productive lands (California DWR, 2014).

A habitat conservation easement is another voluntary legal agreement between a landowner and a qualified conservation organization, imposing use/development restrictions on a specific land segment to protect fish and wildlife habitats. The restrictions vary based on the characteristics of each land and associated natural habitat. For example, it could be practising a controlled and scheduled erosion process on a certain length of land along a river to benefit the bank's expansions. It can eventually restore the natural function of the river by improving sedimentation and erosion processes. In this case, the landowner should also be compensated for associated losses (California DWR, 2014).

A flowage easement grants the required access to a part of a land for seasonal inundation in exchange for the owner's compensation. For example, the easement can be used to form an off-channel salmon habitat within agricultural lands. This can be provided by seasonal flooding of agricultural lands, such as rice fields adjacent to a stream, improving the salmon rearing and migratory habitat. The off-channel habitat enhances salmon’s access to floodplains, significantly increasing the growth rate of juveniles in these fields. Row and truck crops (e.g., corns, sunflowers, and tomatoes) can also be productively farmed while cultivated in occasionally inundated lands, forming a valuable foraging habitat for fish and wildlife species. Occasionally inundating lands may also reduce flood pressures on dikes during high river flow seasons while keeping the land in an active production state when it is not inundated (California DWR, 2014; Yuba County RWMG, 2018).

There is also a valuable chance of modifying some agricultural treatments (practices) for habitat enhancement and protection while appropriate easements are considered to compensate farmers. Although these modifications improve natural habitats, they may either reduce agricultural production or increase related farming costs. These modifications may include (California DWR, 2014):

- implementing the best management practices (e.g., organic farming or hedgerows/buffers installation along streams) to minimize exposure of fish and wildlife species to pesticides;
- inundating orchards’ floors, enriched by native grassland understory, to enhance food availability for salmonids;
- implementing rodent control measures (e.g., vegetative buffers and owl nest box installations) in orchards to protect adjacent dikes; and
- practising wetland crop rotation on agricultural lands, previously located in wetlands, to enhance soil quality (while there is no need for soil fumigation) and increase agricultural production rates.

4.6.3. The Lower Yuba River Accord

The Lower Yuba River Accord (Yuba Accord) was an excellent example of multiple stakeholders' collaboration to share an identical vision for a 20-year water management conflict. The Yuba Accord was one of the area's most significant investments in fish habitat protection. The Yuba River is a substantial habitat for threatened fish species, such as Chinooks and steelhead trout. It is also one of the Feather River's main tributaries, which itself is the major tributary to the Sacramento River - a vital water source in California. Before adopting the Yuba Accord, environmental and fisheries associations had been fighting with YCWA to increase downstream flowrates to restore fish and wildlife habitats. Alternately, YCWA had been trying to keep the constructed dams fully operational to provide sufficient water for hydropower and irrigation as well as water supplies needed to be transferred into other parts of California (Water Education Foundation, 2009).

After a series of long-term conflicts in courtrooms, 18 different stakeholders started collaborating in 2005 and reached a final agreement in 2008 following the implementation of a successful pilot program. The involved entities also formed a River Management Team while committed to providing the team with an annual amount of US$550,000 [CA$704,000] (for more than ten years) from the financial source of transferred water for fisheries research and monitoring systems. The team includes biologists, hydrologists, and engineers from different stakeholders, such as several local, state, and federal agencies (e.g., California Department of Water Resources, YCWA, US Fish and Wildlife Service, National Marine Fisheries Service) as well as environmental non-profit organizations (e.g., Trout Unlimited, The Bay Institute, and South Yuba River Citizens League).

To achieve the agreement, biologists spent two years evaluating the life cycle, population growth, and habitats of salmon and steelhead within a 24-mile river stretch. It was a successful attempt to determine the required monthly flow regime to preserve the fish populations. The River Management Team also suggested several novel strategies to provide sufficient water for multiple uses in the area. Fisheries, Water Purchase, and seven Conjunctive Use Agreements are three major components of the Yuba Accord, tackling fish habitat requirements, needed water supply for export, and groundwater use for local farming, respectively (Water Education Foundation, 2009).

By mimicking the unimpaired hydrological pattern of the study area, the Fisheries Agreement considered less spring and more summer flows within month-to-month flow schedules. This agreement suggested that the instream flow should vary from 262,000 acre-feet to 574,000 acre-feet during extremely dry and wet years, respectively. However, it should be more than 330,000 acre-feet most of the time. While the Water Purchase Agreement considered the dictated flow regimes of the Fisheries Agreement and local availability of groundwater, it enabled YCWA to effectively transfer water to other parts of the State of California. The Water Purchase Agreement determined variable water prices based on the temporal water availability in the area. A portion of the water transfer program's revenue under this agreement was used to finance the implemented research and monitoring systems and some dike improvement projects, such as the dike setback project over the Feather River. To satisfy the requirements of the Fisheries Agreement, YCWA permitted seven water districts in the area to extract 30,000 acre-feet of groundwater during highly dry years under seven Conjunctive Use Agreements. The groundwater is merely allowed to be used for local agricultural purposes. However, the groundwater level would be extensively monitored to fulfil sustainability requirements for the aquifers in the areas. In addition, YCWA provided financial support to replace the traditional motors of diesel pumps with efficient electric motors to reduce their climate impacts (Water Education Foundation, 2009).

4.7. Flood residual risk management

Even after employing all necessary strategies, there is always a residual risk of flood caused by failure/malfunction of flood control facilities, extreme flood incidents, or both. This residual risk can be further managed over time by implementing an enhanced system of flood emergency response, enhanced flood system operations and maintenance, and flood risk management practices (California DWR, 2014).

An enhanced flood emergency response system requires flood hazard assessment, real-time data, and timely flood forecasts. A well-organized contingency planning to conduct coordinated operations among all associated organizations is also essential for effective emergency response. An enhanced operation and maintenance system may include channel improvement, dike maintenance and inspection, and rehabilitation/replacement of hydraulic structures. Federal and state funds may provide resources for floodproofing, elevating, relocating, or demolishing at-risk structures to support flood risk management practices reducing the residual risk. non-governmental organizations may also be another potential funding resource to keep agricultural lands functional and implement environmental enhancement projects as part of flood risk management practices (California DWR, 2014).

4.8. The Knaggs Ranch project: An agricultural floodplain pilot

4.8.1. Background

This case study was a long-term pilot project that assessed the potential benefits of seasonally flooded agricultural lands to providing off-channel rearing habitat for Chinook salmon. It could be considered an example of a successful collaboration between farmers and advocates of salmon and waterfowl. The seasonal rice field inundation led to a significant increase in zooplankton levels and salmon growth by mimicking natural floodplain processes. This multi-benefit project also considered flood management aspects in the area by reducing flood pressure over dikes. Nevertheless, the study emphasized that the experiment's outcomes should not be interpreted to neglect the essential role of natural (i.e., non-agricultural) foraging habitats for salmon runs (Katz et al., 2013; Sommer et al., 2020).

As illustrated in Fig. 8, this case study was implemented through two main phases (two initial pilot projects) within the 1,700-acre Knaggs Ranch situated in the northern parts of the Yolo Bypass. The 59,000-acre Yolo Bypass is approximately five miles west of the City of Sacramento, Central Valley, California. This partially-diked bypass provides the Sacramento River watershed with an additional flood storage capacity during high-flow seasons when Fremont and Wallace weirs (Fig. 8) overtop to reduce flood pressures on upstream dikes. The whole area is covered by flowage easements, making all land uses subservient to flood control activities to protect the Sacramento Metropolitan area. Agricultural land use, in particular rice fields, is the most prevalent land use within the Yolo Bypass. Knights Landing Ridge Cut Canal, connected from the northwest corner to the bypass, routes floodwaters of the Colusa Basin Drain to this area as the main source of irrigation for the rice fields (Katz, 2012; Katz et al., 2013).

Although the California Central Valley hosted a genetically diverse Chinook salmon, extensive diking has adversely affected the salmon runs by decreasing hydrologic connectivity between rivers and floodplains. Alternatively, the Yolo Bypass forms a connection between rivers and floodplains when usually being flooded during springs and winters. This large-scale connection provides fish and waterfowl with a valuable rearing and migratory off-channel habitat. While the fish size at the ocean entry is one of the most influential survival factors for salmon to complete their life cycle, juvenile salmon grow at a higher rate when rearing in off-channel habitats than fish in river channels (Katz, 2012). Lower flow velocities, shallower waters, and richer food sources (e.g., invertebrates) in inundated floodplains make these lands a better foraging habitat for salmon than river channels (Limm & Marchetti, 2009; Sommer et al., 2020). The Knaggs Ranch case study investigates the salmon's behaviour in the seasonally flooded agricultural lands and their response to management strategies for enhancing their growth and survival rates (Katz, 2012).

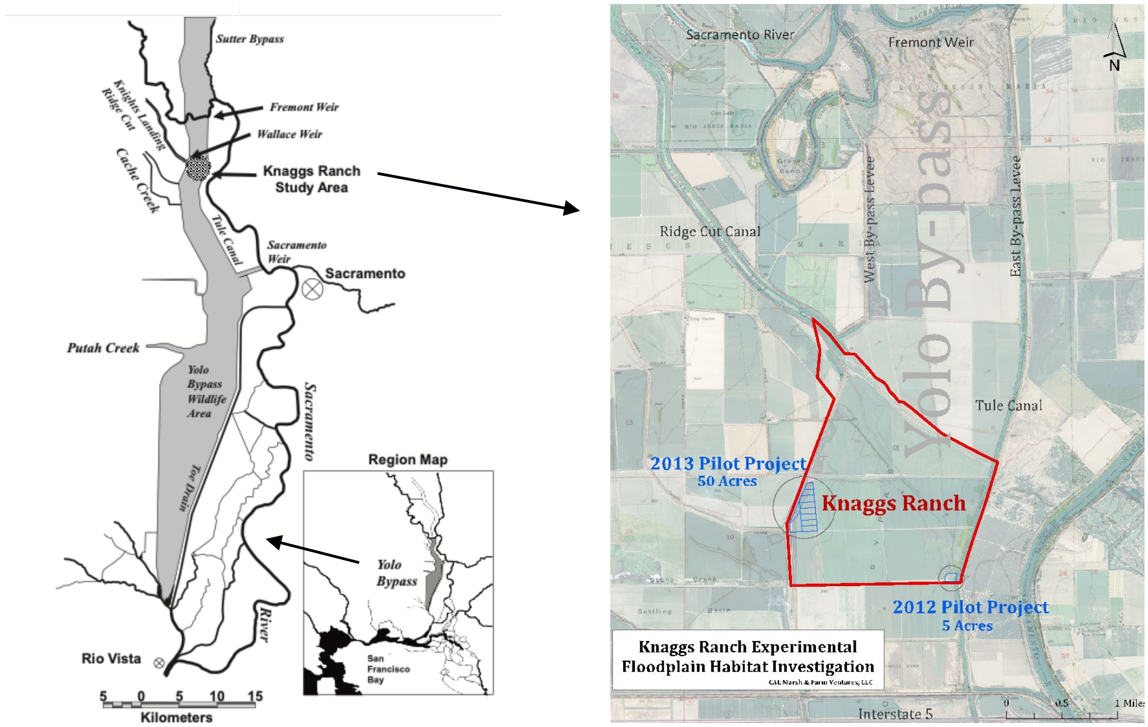


Fig. 8. The study area for the Knaggs Ranch case study (Katz, 2012; Sommer et al., 2020)
Source: Farm to Fish: Lessons from a Multi-Year Study on Agricultural Floodplain Habitat and Projects' Year One Overview

4.8.2. The first phase of the study

Within the project's initial phase, 10,000 juvenile salmon, procured from a fish hatchery on the Feather River, were planted in a 5-acre rice field at the southeast corner of the ranch. While adipose fins of all fish were clipped for identification, 299 fish were implemented with passive integrated transponder (PIT) tags for better tracking. Some of the PIT-tagged fish were distributed into several enclosures across the field, and the rest were freely released into the field. The open-to-the-sky enclosures were constructed using plastic mesh materials to confine the fish stock within a limited area, facilitating the recapturing of the same individuals. Frequent samplings were performed within the study's six-week duration in which all PIT-tagged fish were weighed and measured, and just fork lengths were measured for others. Eventually, the field was drained into the Sacramento River through a canal. Within this canal, fish were counted at the exit point of the field (Katz, 2012).

The evaluation of the mean Fulton's condition factor[13] with a value of 1.21±0.01 in PIT-tagged free-swimming fish indicated extreme robustness among this group of fish. These fish had also mean values of 0.70±0.01 mm/day and 0.11±0.01 g/day for length and weight growth rates, respectively. The mean Fulton's condition factor in PIT-tagged fish in enclosures was 1.18±0.01. The free-swimming fish had higher values of length and weight growth rates due to better diet, fish density, or both within the experiment's first phase. In addition, a good recovery rate of 58% was achieved at the exit point of the rice field, demonstrating excellent fish survival (Katz, 2012). Overall, juvenile salmon attained rapid growth by rearing in the productive off-channel habitat. The appropriate access to off-channel habitat with suitable water quality and desirable temperature enhanced the survival chance of the fish by delaying the time of ocean entry and improving the foraging conditions. Also, this off-channel habitat provided fish with a superior out-migration route decreasing the risk of predation (Katz, 2012).

As the initial phase of the experiment, the first pilot demonstrated a desirable capacity of seasonally flooded agricultural lands to enhance survival and growth rates in juvenile salmon. To expand the study, the following second phase evaluated multiple trials over larger pieces of land and with an extended period of inundation. In addition to the hatchery-origin fish, natural-origin juvenile salmon were also stocked in the second project pilot, as they exhibited more chance of survival in wild environments in previous studies (Araki et al., 2008).

4.8.3. The second phase of the study

In this phase, the effects of various agricultural treatments, habitat types, and prolonged inundation were evaluated on the food web and salmon. Effects of agricultural treatments and habitat types were assessed within a 50-acre field and 0.3-acre field situated over the western corner of the ranch, respectively. Prolonged inundation effects were investigated within a 20-acre study cell located at the southeastern corners of the ranch. The larger 50-acre field (Fig. 8) was the main pilot project in this experiment’s phase, assessing fish responses to agricultural treatments (Katz, 2012; Katz et al., 2013).

4.8.3.1. Response to agricultural treatments

To investigate the effects of agricultural treatments, three types of field substrates, including rice stubble, stomped (bare dirt), and fallow (weedy vegetation), were evaluated for two groups of free-

[13] A non-lethal fish body index representing the ratio of length to weight: k=100,000×Weight (g)Fork Length (mm)3 (Robinson et al., 2008)

swimming fish and penned fish (i.e., confined in several enclosures). These three substrates represent different agricultural management strategies to treat a field. While stubble fields accommodated the highest stem density (60 #/m^2), the stomped field had the lowest one (0.5 #/m^2). Fallow fields had a medium stem density (35 #/m^2) and the highest stem height (0.51 m). In this part of the experiment, the 50-acre pilot were divided into nine replicated subfields (as shown in Fig. 8) with a similar layout and identical water source. There were three randomly assigned replicated subfields for each type of substrate. Various parameters in terms of water quality, abundance and diversity of zooplankton and invertebrate, and survival and growth rates of salmon were measured frequently in each subfield during a six-week study. A total number of 45,000 hatchery-origin fish were planted into the subfields. In case of free-swimming fish, 70 were sampled weekly to be weighted and measured, among which ten fish were frozen for gut content analysis. Each subfield also contained two enclosures to compare responses of hatchery-origin with natural-origin juvenile salmon. To this end, 400 hatchery-origin and 400 natural-origin juvenile salmon were distributed into the enclosures. They had been initially tagged with visible implant elastomer (VIE). About 20 days later, they were tagged with PIT after becoming large enough (Katz et al., 2013).

The results of this part indicated that water temperate had a similar average value of 15.7 °C across all subfields, and values of dissolved oxygen were in the range of 12.19 mg/l to 4.76 mg/l. Turbidity was the parameter that substantially varied among treatments with the highest values in the stomped substrates. While zooplankton levels were high across all substrates, the highest zooplankton density was initially recorded in the stubble subfields. Later, the stubble subfields fell behind two other treatments until the fourth week when they outpaced other substrates again. Also, most macroinvertebrates had the highest density within the fallow substrates. Evaluation of food resource-related parameters showed variability among different parameters during this part of the experiment. However, the stomped substrates generally exhibited a better growth in terms of "Daphnia pulex" as the dominant food resource (i.e., among large-bodied cladocerons) in the experimental subfields. The gut content analysis of salmon and assessment of zooplankton samples also demonstrated that they significantly consumed the large-bodied cladocerons (Katz et al., 2013).

In case of free-swimming fish, the values of mean fork length were similar across all substrates until the fifth week, when the fallow substrate fell behind two other treatments. At the end of this experiment, the fish reared in the stomped substrates had the highest average fork length (i.e., 92.0 ± 0.55). The average Fulton's condition factor over all substrates increased by the value of 0.23 upon this experiment's completion while acquiring the highest growth rate between weeks 3 and 4. Survival rates of free-swimming fish were highly variable among different subfields (i.e., from 0% to about 30%) due to the diverse conditions of this experiment. However, 44% of PIT-tagged free-swimming fish in one of the subfields survived during the entire experiment. The variable morality of fish could also be related to an unexpected delay in initiating the second phase of the experiment (Katz et al., 2013).

In case of penned fish, no statistical difference was detected between hatchery-origin and natural-origin fish in terms of weight and fork length. Also, no significant difference was observed among free-swimming and penned groups of fish; however, samplings for these groups were not performed on identical dates. The lack of a significant difference between hatchery and natural-origin fish can also be justified based on the food abundance and absence of considerable predation within the enclosures. At the end of the study, the average survival rates of penned fish in the stubble, fallow, and stomped substrates were 52%, 82%, and 84%, respectively (Katz et al., 2013). Overall, all substrates provided Chinook salmon with rich food resources, considering the abundance of zooplankton and high densities of invertebrate prey. The average growth rate of Chinook salmon (i.e., approximately 0.93 mm/day during this experiment) and the mean value of Fulton's condition factor (i.e., 1.19 upon the study's completion) demonstrated excellent salmon growth within the whole flooded agricultural land. However, the fish grew faster in the stubble substrate. The gut content analysis showed that Chinook salmon were selectively foraging in areas with large-bodied cladocerans (Katz et al., 2013).

4.8.3.2. Habitat preference

To study the effects of habitat types on attracting salmon (i.e., habitat preference of fish), the PIT-tagged fish were also tracked over two weeks in a 0.3-acre field. This study was performed over the free-swimming fish in conjunction with the previous pilot study. Two circular enclosures were located in sequence inside the 0.3-acre field to assess salmon's preferences to occupy different agricultural substrates. The first enclosure (with respect to the flow direction) was equally divided into three parts to accommodate all previously mentioned substrates. The second enclosure (i.e., the control enclosure) was identically divided but only contained the stomped substrate. The second enclosure was used to check a potential spatial pattern-driven attraction rather than a substrate preference. The movements of PIT-tagged fish were tracked using a series of antennas placed in these circular enclosures (Katz et al., 2013).

Evaluation of the relative number of detections by these antennas indicated that upstream antennas recorded the highest number of detections near the inlet of both enclosures. Considering this preponderance of upstream detections, no significant differences were observed regarding the habitat types and time of detections (i.e., day or night). The significant number of upstream detections can be relevant to the reliance of juvenile salmon on instream flow for food delivery. It should be noted that the habitat types may also influence the detectability; for example, the presence of vegetation may interfere with the detection process (Katz et al., 2013).

Overall, Chinook salmon revealed no strong preference among the tested substrates, formed by different post-harvest treatment strategies of rice fields. However, the fish response to agricultural treatments may be significant while considering other aspects discussed in the previous section.

4.8.3.3. Response to a prolonged inundation

Eventually, to evaluate the effects of an extended inundation time, a 20-acre study cell was developed at the southeast of the Knaggs Ranch, intended to contain water and fish for an extended period. This cell received drained water from its adjacent 200-acre field (kept fallow) after floodwaters receded. In other words, receded water and fish in the 200-acre field were drained into the 20-acre study cell to simulate a prolonged land inundation. The study cell was successfully formed by placing flashboards at drainage points of the adjacent rice field prior to a flood event to control the floodwater recession. Water temperature, transparency, turbidity, and weather parameters were recorded in addition to zooplankton, invertebrate, and fish-related parameters by frequent samplings. The study cell had an outlet to be drained after a prolonged inundation period. A fish sampling at the outlet of the study cell was conducted by beach seining and fyke net trapping. The developed experimental platform extended the inundation time by more than one month (Katz et al., 2013).

The outcomes of this pilot program revealed that it was possible to effectively extend the inundation time by managing the floodwater recession within this case study. However, there were some challenges related to the final drainage of the field with an unexpected, prolonged process and clogging impacts. The study also dealt with limitations in terms of efficient sampling of dispersed fish and the lack of sufficient wild salmon during this experiment. In spite of the small number of captured fish, the outcomes may demonstrate growth benefits for Chinook salmon in the prolonged inundation area (Katz et al., 2013).

This case study's outcomes indicated that the proposed strategy seems like an implementable approach to enhance fish habitats in rice fields close to a salmon's migration corridor with suitable water quality and lower densities of predators. The strategy also requires special considerations in terms of water temperature, water availability, fields' structural integrity to provide sufficient water depth, and appropriate connectivity between fields and the migration corridor. It is unlikely to implement this strategy under warm spring periods, drought conditions, or when it is impossible to maintain a water depth of one metre or more (Sommer et al., 2020).

5. Ōtākaro/Avon River Regeneration Corridor Plan Case Study

5.1. Introduction

Ōtākaro/Avon River Regeneration Corridor Plan (Regeneration Plan) is a fascinating case study as a "living laboratory" illustrating the power of nature to reclaim its rightful unimpaired hydrologic conditions. The Regeneration Plan aims to rebuild a community while proactively considering ecosystem, climate change, natural hazards, and indigenous rights. This "living laboratory" has already experienced adverse impacts that may be expected to happen 50 years later in other places in the world due to climate change effects (Mitchell et al., 2019; Regenerate Christchurch Board, 2019b).

Following the 2010 and 2011 Canterbury earthquakes, a vast residential area within the city of Christchurch, the second-largest city in New Zealand, was destroyed and identified as the "red zone." A land labelled "red zone" is determined unhabitable and uneconomical to timely rebuild. In response, the Crown initiated a buyout program in 2011 through which 5,442 insured properties in the red zone area were purchased by the end of 2015. Following that, built structures were removed from the Crown-owned properties. While the area hosted more than 10,000 people in 2006, fewer than 100 people living nowadays in this abandoned land have suffered from severe liquefaction (Mitchell et al., 2019; Regenerate Christchurch Board, 2019b). Community members have been experiencing highly adverse socio-economic impacts since the time of compulsive relocations. They identified the human desire to tame natural forces rather than work with them in a compatible manner as the main reason for this tragic event (Mitchell et al., 2019). After being abandoned, this land has been trying to revert to its predevelopment conditions by expanding wetlands and vegetation growth.

Recently a high-level plan has been approved to regenerate a vibrant urban area accommodating nature and recreational activities and edge/adaptable houses (Greater Christchurch Regeneration, 2019). This 602-hectare Regeneration Plan area receives about one-third of the Ōtākaro/Avon River catchment runoff, forming a valuable natural ecosystem for the city of Christchurch (Regenerate Christchurch Board, 2019b). The plan identified four major areas of regeneration opportunity, including a 345-hectare land, namely "Green Spine", extended along both sides of the river and three specific reaches located further from the river (Fig. 9).

5.2. The role of indigenous community

Among the various involved entities, members of the indigenous community play a significant role due to their influential cultural and historical roots in this area (Regenerate Christchurch Board, 2019b). The iwi people have been living in New Zealand since approximately 800 years ago. These people from different tribes of Waitaha, Ngāti Māmoe, and Ngāi Tahu had moved into the Canterbury Plains - near Christchurch. Later, they forged an allegiance to be united under Ngāi Tahu (The People of Tahu) (Te Rūnanga o Ngāi Tahu, 2022).

To protect the interest of the iwi people, Te Rūnanga o Ngāi Tahu was established as their tribal council under the Te Rūnanga o Ngāi Tahu Act 1996 (Te Rūnanga o Ngāi Tahu, 2022). In addition to this act, there are two treaties, including Te Ngāi Tūāhuriri and Te Ihutai Ahu Whenua Trust, expecting the Crown's representatives to actively engage this indigenous community in the decision-making process (Regenerate Christchurch Board, 2019b). Hence, Te Rūnanga o Ngāi Tahu along with Christchurch City Council, Canterbury Regional Council, and Ōtākaro limited (i.e., a Crown-owned construction company) were the major organizations involved in the development of the Regeneration Plan.

This plan attempted to properly recognize Mana Whenua's role in the development process to acknowledge the iwi people's historical and territorial rights over the land and protect their cultural values (Regenerate Christchurch Board, 2019a). To this end, the concept of mahinga kai (to work the food) has been incorporated into the planning, design, and development processes. Based on this indigenous concept, various resources should be sustainably managed, like the seasonal migration of the iwi people to sustain food resources. It is an approach to safeguard water resources and green spaces posterity. The use of the Māori language is also considered in the Regeneration

Plan development, which is a practice of respecting the cultural values of the indigenous community.

5.3. Vision, objectives, and strategies

The initial draft of this plan was generated after two years of data collection, analysis, and planning within an extensive stakeholder and public engagement. The feedback from the public and stakeholders led to the determination of the vision and objectives of the Regeneration Plan. Subsequently, different assessment criteria were developed for land use and activity planning concerning these vision and objectives (Greater Christchurch Regeneration, 2019; Regenerate Christchurch Board, 2019b).

"*Our vision is for the river to connect us together with each other, with nature and with new possibilities* (Regenerate Christchurch Board, 2019b)." Having this perspective, the Regeneration Plan envisages the reverted natural state of the area as an opportunity to recreate a resilient community. To this end, this plan considers socio-economic requirements within a predominantly natural environment. Objectives defined under this vision aim at restoring native habitat for birds and native species; enhancing water quality; creating a healthy, vibrant, and sustainable community; attracting residents and visitors; and proactively adapting to natural hazards and climate change.

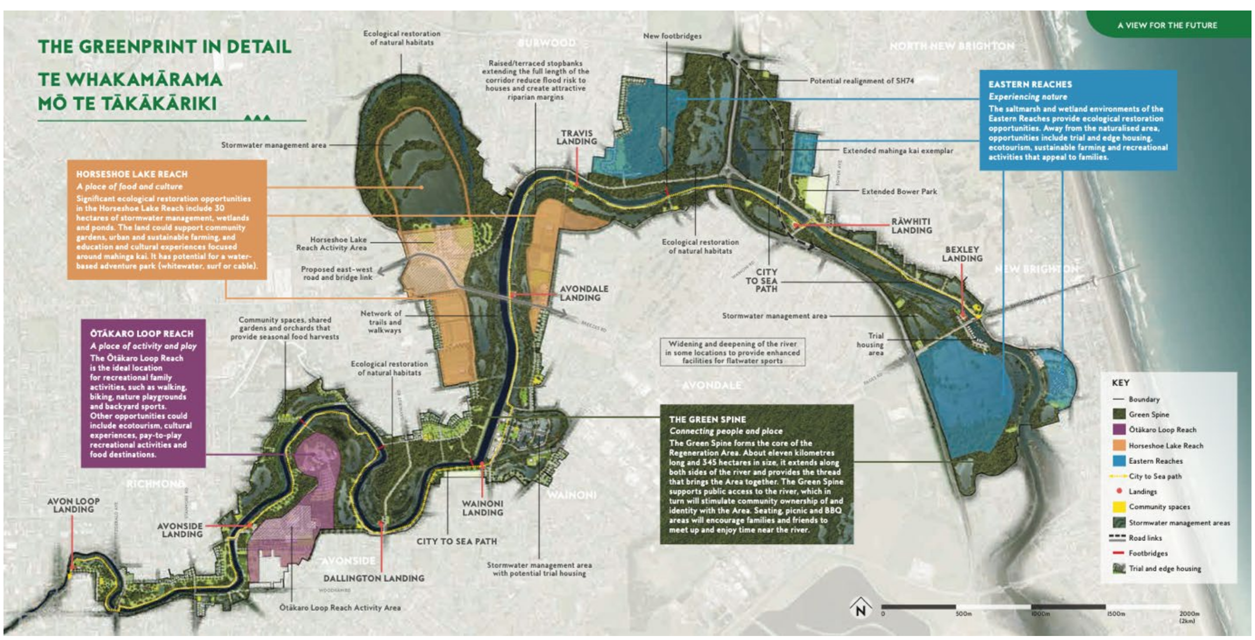


Fig 9. Major areas of regeneration opportunity through the Regeneration Plan
Source: New Zealand Department of the Prime Minister and Cabinet

A set of strategies were suggested to achieve the objectives of the Regeneration Plan. Mahinga kai (work with nature) and connectivity improvement are the backbone of these strategies to enhance the water quality, adapt to natural hazards, and restore the river corridor and native ecosystem. In particular, the regeneration strategies compromise (Regenerate Christchurch Board, 2019b):

- ecological restoration (e.g., naturalizing the river edges and recreating some of the wetlands) and tree planting to provide suitable buffer zones against flooding;
- stopbanks construction with sufficient setback and terraces for forest species to reduce flood risk;
- raising stopbanks over time to adapt to climate change effects;
- nature-based solution (i.e., wetland treatment) to water quality deterioration;
- sustainable farming to support food production and economy;
- establishing Living Laboratory Partnership to advance research and disseminate findings;
- bridges construction to enhance connectivity and resilience of the community;
- realignment of a state highway to improve the river connectivity;
- construction of edge (i.e., on the edge of the regeneration area) and adaptable houses;
- cultural and recreational trails construction depicting stories of the past; and
- potential flatwater sports developments.

However, the latter triggered controversies among stakeholders because of the requirement to increase the depth and width of the river (Greater Christchurch Regeneration, 2019). Each of the above-mentioned strategies was located based on specific characteristics of each area of regeneration opportunity. For example, sustainable farming will be implemented within the reaches with high-quality agricultural soils. In most areas, the pre-earthquakes residential character will likely change to the predominantly natural character or open parkland.

5.4. Implementation

5.4.1. A phased approach implementation

The regeneration process is a long-term, multi-decade project in which the implementation encompasses three phases with short-, medium-, and long-term perspectives, respectively. The first phase aims to develop a comprehensive platform to increase confidence in the benefits and success of the Regeneration Plan. It entails the establishment of a regulatory and governance system to effectively coordinate all stakeholders as well as the development of a detailed implementation plan. The implementation plan prioritizes different capital projects, determines funding strategies, and develops design guidelines and a progress monitoring system. Approximately 58% and 35% of the lands within the regeneration area are respectively owned by the Crown (i.e., Land Information New Zealand on its behalf) and Christchurch City Council, while the rest is in private ownership. In this initial phase, it is also necessary to amalgam various ownership titles before implementing the Regeneration Plan's strategies (Regenerate Christchurch Board, 2019b).

Within the second phase, preliminary steps should be taken to encourage people to be involved in the projects and gradually return to the area. This public engagement could be interpreted as the initial signs of successful regeneration. To this end, prioritized projects should be started on the ground to attract people into the area. For example, early construction of an 11 km city-to-sea path can be initiated, and ecological restoration can also be started by cultivating vegetation and tree planting (Regenerate Christchurch Board, 2019b).

The third phase, with a 10-year time span, will lead to the completion of the projects, restoration of native habitat, reduction of the river's contaminants, a more vibrant city with stronger tourism industry, and more resilient infrastructures. Eventually, multiple values of the indigenous community, including kaitiakitanga (protecting the ecosystem for the next generation), hauora (elevating well-being), whakapapa (enhancing relationship with the natural environment) and matauranga (transferring knowledge), will be achieved through practising mahinga kai (Regenerate Christchurch Board, 2019b).

Successful Regeneration Plan implementation requires long-term investment, collaboration, and commitment from all associated stakeholders. The private, community, non-profit, and philanthropic sectors can provide multiple funding sources. However, technical analysis indicates that the plan's broad range of local and national benefits will exceed its overall costs (Greater Christchurch Regeneration, 2019; Regenerate Christchurch Board, 2019b). It can just provide the city with A$1.6 billion [CA$1.46 billion] of economic benefits (Christchurch City Council, 2019). Initial funding of A$40 million [CA$36.4 million] was agreed to be provided from the Christchurch Regeneration Capital Acceleration Facility to commence the Regeneration Plan's implementation which is required to be followed by A$300 million [CA$273 million] from the Government budget to implement the regeneration projects. The initial A$40 million [CA$36.4 million] funding is intended to be used within the second phase of the implementation process for:

- creating pathways across the regeneration corridor to enhance connectivity;

- constructing several essential public facilities; and
- initiating restoration of ecological areas based on a predefined list of priorities.

Attracting residents and new economic activities are the key components for securing more essential funding resources to fully implement the Regeneration Plan (Christchurch City Council, 2019).

5.4.2. Regulatory system

The plan is consistent with and developed under the Greater Christchurch Regeneration Act 2016, providing various tools to support regeneration activities in this area. This act establishes the required regulatory system to guarantee the implementation of the Regeneration Plan. Therefore, a wide range of regional plans, acts, and activities must be consistent with the Regeneration Plan to be allowed to be practised in the area. Relevant organizations should appropriately amend some documents to reflect the Regeneration plan's vision and objectives. For example, Christchurch District Plan (2017), regulating sustainable resource management in the area, and Canterbury Land and Water Regional Plan, setting frameworks and objectives for land and water resources management, should be respectively modified by Christchurch City Council and Canterbury Regional Council (Regenerate Christchurch Board, 2019b).

These changes would include replacing the entire/part of a provision, wording modification, and adding new sections and chapters. A specific chapter about Ōtākaro/Avon River Corridor Regeneration Plan will be added to consider all plan's objectives. It will define intended activities in the Green Spine and three other reaches, such as stormwater management and construction of flood protection infrastructures in the Green Spine. In this direction, the Mahinga kai concept will be incorporated into new Land and Water Regional Plan policies to improve water quality and perform ecological restorations. The historical values of the indigenous people will also be considered in earthworks and land development in this area. Particularly, a new section will define building setbacks from infrastructures considered in the Regeneration Plan (e.g., in stopbanks or stormwater management areas). Permitted, discretionary, and restricted land uses and activities with their corresponding rules will be determined for each area. The maximum footprint of a single building, site coverage of all buildings, and area covered by impervious surfaces will also be defined in the Green Spine and three reaches (Regenerate Christchurch Board, 2019a).

6. Conclusions

The present flood protection system in the Lower Mainland is unlikely to withstand the growing flood risk due to climate change, ageing flood control structures (including about 600 km of dikes), and lack of a risk-based and collaborative management approach. The structural protection system also negatively impacted salmon runs in the area, mainly through fish passage blockade, deterioration of habitat and water quality. The present system disproportionally affects indigenous communities through a wide range of socio-economic consequences, such as locating their communities in flood-prone lands, excluding them from the decision-making process, and reducing their source of food and income. Evaluation of different case studies in the United States and New Zealand indicated that the areas protected by conventional structural measures (e.g., extensive systems of dikes) frequently experienced substantial flood incidents with significant financial burdens. The human desire to tame natural forces rather than work with them was the main reason for many tragic events.

Integrated floodplain management (IFM) is a highly beneficial alternative that can proactively reduce flood risk while considering the local and provincial values of all stakeholders and affected communities. Effective implementation of IFM generates a greater benefit for flood control authorities, agricultural associations, fisheries and environmental advocates, indigenous communities, and water resource managers. Considering the substantial correlation between climate change actions and IFM, practising the IFM-based plan's objectives, strategies, and projects may also enhance regional climate change adaptation over time. To implement an IFM-based approach, it is necessary to

- change the "entrenched pathways" towards the application of traditional, single-benefit flood control approaches;
- build trust among all influential stakeholders and affected communities through a shared vision with specific objectives and measurable performance metrics;
- secure multi-source funding (e.g., public and private grants, user fees, revenue bonds, property tax, and donations) to develop IFM-based plans and implement associated projects; and
- practice an adaptive management system by establishing a neutral backbone organization (e.g., a private non-profit organization supported by all involved entities).

The coordinating body should implement a well-designed outreach program to identify and engage a broader spectrum of stakeholders and affected communities. Based on real-world case study experiences, a cycle of discussion, agreement, and action should be pursued to collaboratively expand the scale of the multi-benefit projects. Scaling-up this work can be achieved by the building trust and incorporating equally weighted values of more entities into the cycle of collaboration. Smaller-scale, less integrated projects can be implemented as the initial actions with multiple measurable benefits may eventually lead to fully integrated concrete actions through the collaboration. To practice IFM as a widespread norm within a watershed, various overarching concepts should also be promoted, including "collaborative culture, local capacity, policy reinforcement, sustained funding, and driving public and private markets."

IFM usually entails long-term, multi-decadal plans and projects in which an implementation plan may have short-, medium-, and long-term perspectives. The implementation plan prioritizes different capital projects, determines funding strategies, and develops design guidelines and a progress monitoring system. Successful implementation requires long-term investment, collaboration, and commitment from all associated entities through "persistence, flexibility, and patience." As part of the plan implementation actions, frequent meetings should be held to monitor the IFM-based plan's progress regarding performance metrics, sustain project funding from diverse sources, and update the plan based on new guidelines and project outcomes. It is also necessary to harmonize the current regulatory/policy tools (e.g., permitting processes for projects) with IFM's vision and objectives. A confusing and time-consuming permitting process may significantly hinder IFM implementation. Establishing a dedicated "permit assistance team" from different involved entities to build a body of knowledge and manage the permitting may ameliorate the process. A list of works needs to be permitted, a list of required permits, a description of permits and their objectives, and good examples of applications should be provided. Efficient data management is also in great demand to enhance the transparency and integration level of the projects. It can be practised by developing a well-designed website for data collection and dissemination.

The evaluation of the case studies and projects proved that the short- and long-term benefits of IFM significantly exceed its considerable initial costs. Some benefits of IFM are enhanced public safety, fish and wildlife habitat restoration, farmlands protection, local economy improvement, GHG emissions reduction, stakeholder collaboration improvement, enhancement of the financial and technical capacities of indigenous communities, and reconciliation. Additionally, a failure to implement effective IFM may lead to detrimental consequences, such as significant flood costs and loss of biodiversity including at-risk species.

The reviewed documents successfully implemented specific strategies to attain multiple benefits of flood risk reduction, agriculture protection, and fish and wildlife habitat restoration. These strategies include:

- replacement of river edge dikes with setback dikes to increase floodplain storage capacity, recharge groundwater, and enhance side-channel habitat and river connection;
- replacement of conventional floodgates with new self-regulating floodgates enhancing fish migratory access while keeping the same level of flood protection;
- relocation and enhancement of ditches and their associated culverts blocking fish passage;
- Establishment of agricultural conservation, habitat conservation, and flowage easements to simultaneously maximize using floodplains as fish and wildlife habitats and minimize the conversion of agricultural lands;
- Modification of some agricultural treatments to enhance fish and wildlife habitat, such as organic farming treatments, wetland crop rotation, and orchards' floors inundation;
- regulation of upstream flow rates based on the required monthly flow regime to preserve the fish populations downstream while providing other sectors with sufficient water;
- seasonally inundation of rice fields with various treatments to create off-channel habitat for Chinook salmon while keeping agricultural lands functional;
- the use of engineering log jams through the placement of woods to reduce water velocity, increasing slow-edge fish habitat; and
- enhancement of native vegetation pattern through planting trees, shrubs, and/or willow stakes, restoring wildlife habitat.

However, some of these strategies should be incorporated consistently with effective land-use planning and following an agreement with landowners. Properly compensating owners for short-term and long-term economic losses may be essential.

The outcomes of IFM-based plans and their projects and strategies indicated significant benefits of this flood management approach in terms of climate change, indigenous rights, agricultural land preservation, ecosystem restoration, and flood risk. From this perspective, there is an urgent need to actively shift from the conventional flood management approaches to IFM-based approaches.

7. References

Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., Gottwald, S., Guerrero, P., Nicolas, C., & Matzdorf, B. (2019). Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? *Landscape and Urban Planning*, *182*(October 2018), 12–21. https://doi.org/10.1016/j.landurbplan.2018.10.003

Araki, H., Berejikian, B. A., Ford, M. J., & Blouin, M. S. (2008). Fitness of hatchery-reared salmonids in the wild. *Evolutionary Applications*, *1*(2), 342–355. https://doi.org/10.1111/j.1752-4571.2008.00026.x

Baker, J. (2013). *Fisher Slough Freshwater Tidal Marsh Restoration - Final Reprot*. https://salishsearestoration.org/images/d/d9/NOAA_FISHER_SLOUGH_FINAL_REPORT.pdf

Beamer, E., & Henderson, R. (2016). *Fisher Slough Floodgate Report for Water Year 2015*. http://skagitcoop.org/wp-content/uploads/FisherSloughFGReportWY2012Final.pdf

Beamer, E., Henderson, R., Ruff, C., & Wolf, K. (2017). *Juvenile Chinook Salmon Utilization of Habitat Associated With the Fisher Slough Restoration Project, 2009-2015*. skagitcoop.org/wp-content/uploads/2015-FisherSl-Chinook-04-26-17_Final.pdf

BfG. (2020). *LIFE-Project 'LiLa – Living Lahn.'* The German Federal Institute of Hydrology. https://www.bafg.de/EN/Home/lila.html

California DWR. (2014). *Feather River Regional Flood Management Plan*.

California DWR, & USACE. (2013). *California's Flood Future: Recommendations for Managing the State's Flood Risk*. http://www.water.ca.gov/sfmp

Christchurch City Council. (2019). *Ōtākaro Avon Regeneration Plan River Corridor - Single Stage Programme Investment Case for the Christchurch Regeneration*.

City of Vancouver. (2018). *Coastal Adaptation Plan Fraser River Foreshore - Final Report*.

District of Squamish, & Kerr Wood Leidal. (2017). *Squamish Integrated Flood Hazard Management Plan*.

Dutch Water Sector. (2022). *Room for the River Programme*. https://www.dutchwatersector.com/news/room-for-the-river-programme

Ecology. (2021). *Comprehensive Planning for Flood Hazard Management: A Guidebook*.

ECONorthwest. (2012). *Socioeconomic Benefits of the Fisher Slough Restoration Project*. https://salishsearestoration.org/images/f/f6/Weinerman_et_al_2012_fisher_slough_economic_benefits.pdf

European Commission. (2022). *Living River Lahn - one river, many interests*. Life Public Database. https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=5438

Floodplains by Design. (2016). *Advancing Integrated Floodplain Management at the Local Level*. https://www.floodplainsbydesign.org/wp-content/uploads/2017/07/Advancing-Integrated-FP-Mgmt_final-7-15-16.pdf

Forest Research. (2022). *Slowing the Flow at Pickering*. Great Britain's Forestry Commission. https://www.forestresearch.gov.uk/research/slowing-the-flow-at-pickering/

Fraser Basin Council. (2016a). *Lower Mainland Flood Management Strategy - Phase 1 Summary Report*.

Fraser Basin Council. (2016b). *Lower Mainland Flood Management Strategy Analysis of Flood*

Protection Infrastructure, Practices and Policies.
Fraser Basin Council. (2021). *Investigations in Support of Flood Strategy Development in British Columbia - Summary Report*. www.reddragonconsulting.com
Fraser Basin Council, & Ebbwater Consulting. (2021a). *Investigations in support of flood strategy development in British Columbia - Issue A-1: Flood Risk Governance*. https://www.fraserbasin.bc.ca/_Library/Water_Flood_BC/A-1_Flood_Risk_Governance.pdf
Fraser Basin Council, & Ebbwater Consulting. (2021b). *Investigations in Support of Flood Strategy Development in British Columbia - Issue B-3: Flood Risk Assessment*. https://www.fraserbasin.bc.ca/_Library/Water_Flood_BC/A-1_Flood_Risk_Governance.pdf
Greater Christchurch Regeneration. (2019). *Report on decision made in approving the draft Otakaro Avon River Corridor Regeneration Plan*. https://dpmc.govt.nz/sites/default/files/2019-08/MGCR Signed - Report on Decisions made in approving the Draft Otakaro Avon River Corridor Regeneration Plan.pdf
Katz, J. (2012). *The Knaggs Ranch Experimental Agricultural Floodplain Pilot Study - Year One Overview*. https://watershed.ucdavis.edu/files/biblio/Knaggs Ag Floodplain 2012 Overview Final.pdf
Katz, J., Jeffres, C. A., Conrad, L., Sommer, T. R., Corline, N., Martinez, J., Brumbaugh, S., Takata, L., Ikemiyagi, N., Kiernan, J., & Moyle, P. (2013). *The Experimental Agricultural Floodplain Habitat Investigation at Knaggs Ranch on Yolo Bypass - Year Two Results*. https://data.sacriver.org/assets/06942155460a79991fdf1b57f641b1b4/application/pdf/Knaggs_2013_final_BOR_report_0.pdf
King County's DNRP. (2007). *2006 King County Flood Hazard Management Plan*. *January*. https://your.kingcounty.gov/dnrp/library/2007/kcr826-2006.pdf
King County. (2021). *Reddington Levee Setback Project*. dnrp/wlr/sections-programs/river-floodplain-section/capital-projects/reddington-levee-setback-and-extension.aspx
Knox, R. L., Wohl, E. E., & Morrison, R. R. (2022). Levees don't protect, they disconnect: A critical review of how artificial levees impact floodplain functions. *Science of the Total Environment*, *837*(April), 155773. https://doi.org/10.1016/j.scitotenv.2022.155773
Limm, M. P., & Marchetti, M. P. (2009). Juvenile Chinook salmon (Oncorhynchus tshawytscha) growth in off-channel and main-channel habitats on the Sacramento River, CA using otolith increment widths. *Environmental Biology of Fishes*, *85*(2), 141–151. https://doi.org/10.1007/s10641-009-9473-8
McCarthy, S., Gregersen, C., Akyuz, K., Brandt, L., & Koon, J. (2014). *Reddington Levee Setback Project Year 1 Monitoring Report*. https://your.kingcounty.gov/dnrp/library/water-and-land/flooding/2014-Reddington-Year-1-Monitoring-Report.pdf
McCarthy, S., Koon, J., Berge, H., Lantz, D., & Peters, E. (2013). *Reddington Levee Setback Habitat Monitoring Plan* (Issue March). https://your.kingcounty.gov/dnrp/library/water-and-land/flooding/capital-projects/reddington-habitat-monitoring-plan-april2013.pdf
Mitchell, C., McGregor, I., & Williams, A. (2019). *Red to Green The Evolution of a City's Abandoned Acres*. Stuff. https://interactives.stuff.co.nz/2019/09/christchurch-red-zone-to-green/
Mohammadiun, S., Yazdi, J., Hager, J., Salehi Neyshabouri, S. A. A., Sadiq, R., Hewage, K., & Alavi Gharahbagh, A. (2020). Effects of bottleneck blockage on the resilience of an urban stormwater drainage system. *Hydrological Sciences Journal*, *65*(2). https://doi.org/10.1080/02626667.2019.1690657
Mohammadiun, S., Yazdi, J., Salehi Neyshabouri, S. A. A. A. A., & Sadiq, R. (2018).

Development of a stochastic framework to design/rehabilitate urban stormwater drainage systems based on a resilient approach. *Urban Water Journal*, *15*(2). https://doi.org/10.1080/1573062X.2018.1424218

NY Moors National Park. (2022). *Slowing the Flow*. North York Moors National Park Athority. https://www.northyorkmoors.org.uk/looking-after/our-projects-and-partnerships/previous-projects/slowing-the-flow

Regenerate Christchurch Board. (2019a). *Amendments to Resource Management Act Documents*. https://dpmc.govt.nz/sites/default/files/2019-08/Appendix One - Amendments to Resource Management Act Documents.pdf

Regenerate Christchurch Board. (2019b). *Ōtākaro Avon River Corridor Regeneration Plan*. https://dpmc.govt.nz/sites/default/files/2019-08/Otakaro Avon River Corridor Regeneration PlanReducedSize.pdf

Rijke, J., van Herk, S., Zevenbergen, C., & Ashley, R. (2012). Room for the river: Delivering integrated river basin management in the netherlands. *International Journal of River Basin Management*, *10*(4), 369–382. https://doi.org/10.1080/15715124.2012.739173

Robinson, M. L., Gomez-Raya, L., Rauw, W. M., & Peacock, M. M. (2008). Fulton's body condition factor K correlates with survival time in a thermal challenge experiment in juvenile Lahontan cutthroat trout (Oncorhynchus clarki henshawi). *Journal of Thermal Biology*, *33*(6), 363–368. https://doi.org/10.1016/j.jtherbio.2008.05.004

Schmidt, S., Guerrero, P., & Albert, C. (2022). Advancing Sustainable Development Goals with localised nature-based solutions: Opportunity spaces in the Lahn river landscape, Germany. *Journal of Environmental Management*, *309*(February), 114696. https://doi.org/10.1016/j.jenvman.2022.114696

Slowing the Flow Partnership. (2016). *Slowing the Flow Partnership Briefing: Boxing Day 2015 Flood Event*. https://cdn.forestresearch.gov.uk/2022/02/160329_pbeck_boxing_day_2015_final.pdf

Sommer, T., Schreier, B., Conrad, J. L., Takata, L., Serup, B., Titus, R., Jeffres, C., Holmes, E., & Katz, J. (2020). Farm to fish: Lessons from a multi-year study on agricultural floodplain habitat. *San Francisco Estuary and Watershed Science*, *18*(3), 1–20. https://doi.org/10.15447/SFEWS.2020V18ISS3ART4

Te Rūnanga o Ngāi Tahu. (2022). *Ngāi Tahu – the iwi*. Ngāi Tahu's Tribal Council. https://ngaitahu.iwi.nz/ngai-tahu/

Tetra Tech. (2009). *Fisher Slough Final Design and Permitting Final Basis of Design Report*. https://www.skagitcounty.net/PlanningAndPermit/Documents/FisherSlough/DesignReport/RFP-COPY_TNC_FISHER_TIDAL_MARSH_FINAL_BASIS_OF_DESIGN_REPORT.pdf

TNC. (2014). *Floodplains by Design: A New Approach to Manage River Corridors in Puget Sound*.

TNC. (2016). *Vision, Strategies and Actions for Puget Sound Major River Floodplains*. The Nature Conservancy and consultants

TNC. (2017). *Restoring the Tides - Monitoring the Benefits of Restoration for Farms, Fish and Flood Control at Fisher Slough: A Seven-Year Synthesis*. https://waterviewconsulting.com/wp-content/uploads/2021/04/Restoring_the_Tides_Monitoring_the_Benefits_of_Restoration_for_Farms_Fish_and_Flood_Control_at_Fisher_Slough_A_Seven-Year_Synthesis.pdf

TNC. (2018a). *Floodplains by Design: A 5-Year Strategy for Washington's Floodplains*.

TNC. (2018b). *Floodplains by Design: Towards a New Paradigm*.

Van Herk, S., Rijke, J., Zevenbergen, C., Ashley, R., & Besseling, B. (2015). Adaptive co-management and network learning in the Room for the River programme. *Journal of Environmental Planning and Management*, *58*(3), 554–575. https://doi.org/10.1080/09640568.2013.873364

Water Education Foundation. (2009). *The Lower Yuba River Accord Overview*. https://doi.org/https://www.yubawater.org/DocumentCenter/View/84/Lower-Yuba-River-Accord-Overview-PDF

WRIA 9. (2005). *Salmon Habitat Plan 2005*.

WRIA 9. (2021). *Salmon Habitat Plan 2021 Update*. https://www.govlink.org/watersheds/9/pdf/2021_PlanUpdate.pdf

Yazdi, J., Mohammadiun, S., Sadiq, R., Salehi Neyshabouri, S. A. A. A. A., & Alavi Gharahbagh, A. (2018). Assessment of different MOEAs for rehabilitation evaluation of Urban Stormwater Drainage Systems – Case study: Eastern catchment of Tehran. *Journal of Hydro-Environment Research*, *21*(January 2017), 76–85. https://doi.org/10.1016/j.jher.2018.08.002

Yuba County RWMG. (2018). *Yuba County Integrated Regional Water Management 2018*.