Planning and Assessment of Water Resource Project in an Uncertain Climate Future: Application of Hydro-Economic Simulation Framework

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DECLARATION

I, Saba Batool, 2015PIDEFMPHILENV012 hereby declare that I have produced the work presented in this thesis, during the scheduled period of study. I also declare that I have not taken any material from any source except referred to wherever due that amount of plagiarism is within acceptable range. If a violation of HEC rules on research has occurred in this thesis. I shall be liable to punishable action under the plagiarism rules of the HEC

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Dedication

This work is dedicated to my beloved parents, sister, brother and my best friend, Akbar khan

ABSTRACT

In this research we developed an integrated framework for economic assessment. Such assessment of water resource project conducted in the context of climatic and development uncertainties. Two level of simulation forms the framework: the hydrological based on linear regression equation of weir structure; and the economic. The economic aspects utilize the Monte Carlo Simulation Techniques to simulate the net present value of projects given variation in economic model parameters. In this research we include the linkages between climate and the performance of the system: changes in runoff as well as economic changes in the agriculture production. There exist huge uncertainties surrounding the magnitude and the speed of climate change. How such uncertainties change the government project decision by selecting discount rate is the main question addressed in this paper. The research focuses on the various complex aspects relating to water resource planning that lead to tiresome effort in the calculation of net benefits from new investment. This is due to uncertainties relating to climate change and future development prospects. The framework was made operational for a real-world planning application in the six flood dispersal structure project of Baluchistan. A projected climate scenario, drawn to reduce the uncertainty factor from climatic future by utilizing Historical data and generate flow series by using representative concentration pathways (RCPs). The research was then extended to evaluate the costs and benefits of constructing alternative configurations of weir structure project, for four conceivable water withdrawal conditions and a range of climatic scenarios. An approach was in this manner created to analyse the feasibility of project across a range of conditions. Several climate change linkages were found to have important effects on the system and the economics of the project: climate-perturbed runoff because of precipitation changes. Given this large spread and the particularly strong negative effect of reduced (and highly uncertain) runoff in the river, additional sensitivity analyses were conducted over a wider range of inflow changes, including all climate linkages and the RCP 4.5 and 8.5 scenario precipitation projections. These experiments show that economic outcomes are highly sensitive to changes in inflows. The value of dam is lower in historical condition as compare to the other climatic scenario. The results further indicate failure in sensitivity test analysis to meet the future demand of water in both climatic scenarios. The water balance shows a deficit in historical data as well as in case of high irrigation demand. Climate impact assessment should be a core part of every project that deal with natural resources.

Keywords*: Water Resource, Nari River, Representative concentration pathways, Monte Caro simulation, discounting, Net Present Value, Uncertainty.*

Pakistan Institute of Development Economic

CERTIFICATE

This is to certify that this thesis entitled: **"Planning and Assessment of Water Resource Projects in an Uncertain Climate Future: Application of Hydro-Economic Simulation Framework."** submitted by Saba Batool is accepted in its present form by the Department of Environmental Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in **Master of Philosophy in Environmental Economics**.

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List of Acronyms:

UNFCC = United Nations Framework Convention on Climate Change

IPCC = Intergovernmental Panel on Climate Change

Mm = Millimeter

Bcm = Billion Cubic Meter

Mcm = Million Cubic Meter

Ft = foot/feet

M = meter

Sq. kms = Square Kilometers

PMD = Pakistan Meteorological Department

°C = Degree Centigrade

IWRM = Integrated Water Resource Management

PIU = Project Implementation Unit

GCM's = Global Climate Models

HKH = Hindu Kush-karakaram Himalaya

ENSO = El-Nino/ Southren Osoiliation

MCDM = Multi Criteria Decision making

RCM = Regional Climate models

SWAT = Soil and Water Assessment Tools

GDP = Gross Domestic Product

KGS = Kolmogorov- Smirnov

CI = Confidence Interval

CO_2 = Carbon-dioxide Emissions

AR(4) = Fourth Assessment Report

S_1 = represents the 3 weir structure include Haji Sheher, Erri & Mithri.

S_2 = represents the 3 weir structure include Khokar, Tuk & Ghazi.

IRR = Internal Rate of Return

EIRR = Economic Internal Rate of Return

FIRR = Financial Internal Rate of Return

NPV = Net Present Value

O&M = Operation and Maintaince Cost

PC_1 = Planning Commission Report 1

CHAPTER: 1 INTRODUCTION

1.1 Climate change:

According to IPCC, *"Change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity".*

The definition of climate change according to United Nations Framework Convention on Climate Change (UNFCCC) is, *"Change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods."*

Climate change is a reality and its impacts on health, water, agriculture, forest, socio-economic sector, and biodiversity are evident around the world. Least developed and developing nations, according to Parry, Canziani, Palutikof, van der Linden, and Hanson (2007) are more vulnerable to the climate change and projected to suffer more as compared to the developed countries. Pakistan in particular, comes under most vulnerable countries to climate change because of its warm climate. Geographically, Pakistan is the region where the increase in temperature is projected to be higher than the global average temperature. Most of its land is semi-arid and arid with almost sixty per cent of its area receives less than 250 mm of precipitation per year. The rivers of the region are mainly fed by the Himalayan Hindu Kush glaciers which are reporting a receding trend speedily due climatic variability. Most important part of Pakistan economy is agriculture sector which contribute 23.4% in economy.(Syed Ali Raza, Ali, & Mehboob, 2012; Usman, 2016). Dependence on agriculture is one of the reasons of being highly sensitive to changing climate. And because of the variability in the monsoon, the country is at larger risk as the droughts and floods are more frequent and intensive. Under the impact of all the factors involved, there are serious threats to the food security, energy, and water security of the country.

1.2 Social discounting:

Discounting refers to the idea that a specified amount of available resources for today's use are of more worth than the same available amount in the future. This argument has two sides; firstly, resources can be made productive today through investment, and such that the yields will be greater in the future. While the resources that will be present in the future can be put to productive use later. On the other hand, individual time preferences are also justifiable measures of discounting, since the consumption of the resources is consistently favoured at present over the future by the people and community. This is what happened in case of Baluchistan, the locals used the resource in present and ground water tables goes beyond the capacity of natural recharge. Now the masses of Baluchistan faced shortage of water and it is not available for the future generation. Under this situation government of Baluchistan can put the resource in a more productive use by investment. So the benefit will be available for the present generation as well as future generation. Competitive markets in an ideal situation result in the setting of competitive discount rates that allow the individuals to utilize the available resources in an inter-temporal efficient manner determined by their time preference. On the contrary the real situation is entirely different. The social discount rates are not wholly reflected by the market choices that appropriately take into account the present and future social benefits and costs. Therefore, it is a complex exercise to determine a single discount rate for assessment of long-lived investment programs. According to PC_1 report Nari River, six flood dispersal structures project of

Baluchistan is one of the highest investment projects in Pakistan to resolve the issue of underground water depletion. They built 6 flood dispersal structures on Baluchistan second largest river for efficient utilization and equal distribution of water in province. The project water availability is dependent on the climatic condition of Baluchistan (especially in monsoon period) which makes the evaluation of project highly uncertain not only in terms of selection of discount rate but also the climatic and development uncertainty. Goulder and Williams (2012) explains that we choose both discount rate (either lowest or highest) depends on what public project want to achieve. They differentiate between a social welfare equivalent discount rate suitable for deciding whether a certain policy would enhance social welfare and a finance equivalent discount rate appropriate for deciding whether the potential Pareto improvement will be offered by the policy. If the purpose of project is to improve well-being of society then the selection of discount rate should be lowest which is not used in this project they used higher discount rate. While the objective of project shows their aim is to improve the well-being of society. The Pareto improvement in this case cannot be achieved because the resource has exhausted because of action of present generation and both generations will suffer the loss. Now under this project, the property rights of perennial flow are available to Sibi. Rest of the flood water is transferred to district Kachhi. If future climatic condition is not in favour, benefits reduced for other districts except Sibi the benefit become zero or negative because water storage depends on rainfall and flood. If monsoon pattern shows a changing trend, then the availability of water for future generation remains under question. Moreover, changing monsoon pattern can have an impact on agriculture, because water requirement for the crop at right time is crucial. Therefore, the right pick of discount rate is also crucial while assessing the climate change policy. Plenty of climate-related welfares from existing policy efforts would take the shape of avoided damages in the future; while the costs for those avoided damages would be borne now. Thus, the present value of benefits shrinks in a high consumption discount rate comparative to the present value of costs and the case of current aggressive action weakens. Comparatively, minor differences in the discount rate choices can bring major differences in the policy valuation. There is a significant disagreement in the issue of discount rate. The Stern (2006) attained considerable attention in supporting a policy of 3 percent reduction in greenhouse gas (GHSs) emissions per year relative to business as usual, which should be started immediately. This Review suggested that a consumption discount rate should be 1.4%. But numerous experts, importantly Mendelsohn (2008); Nordhaus (2006) criticized the Stern's rate that his rate is low and inappropriate and conclusions of his report are not well originated. Nordhaus's Dice model employed the discount rate of about 4.3 percent, which in his view is modest compared to Stern's employed discount rate. Stern's discount rate is higher which in Nordhaus's view gives a concrete justification of the climate action. The difference in the discount rates in the models of Stern and Nordhaus present a more aggressive climate policy recommended by Stern and modestly supported by Nordhaus.

1.3 Social discounting related with climate change:

The discounting debate is in a quagmire of many countering arguments and suggestions. Nordhaus (2006) advocates making immediate investments to curb climate change although the discount rate suggested by him is relatively low compared to the normal value of 4 used in practice. Cline (2007); Stern (2006) also recommend immediate action based on use of low discounting rates. In Sterner and Persson (2008) view, discounting results from the internalization of reduced natural wealth consumption and consumption as a result of damages caused by climate change. M. Weitzman (2007); M. L. Weitzman (2009) perceives action based on uncertain effects and the necessity to circumvent the low risk damages of climate change. In

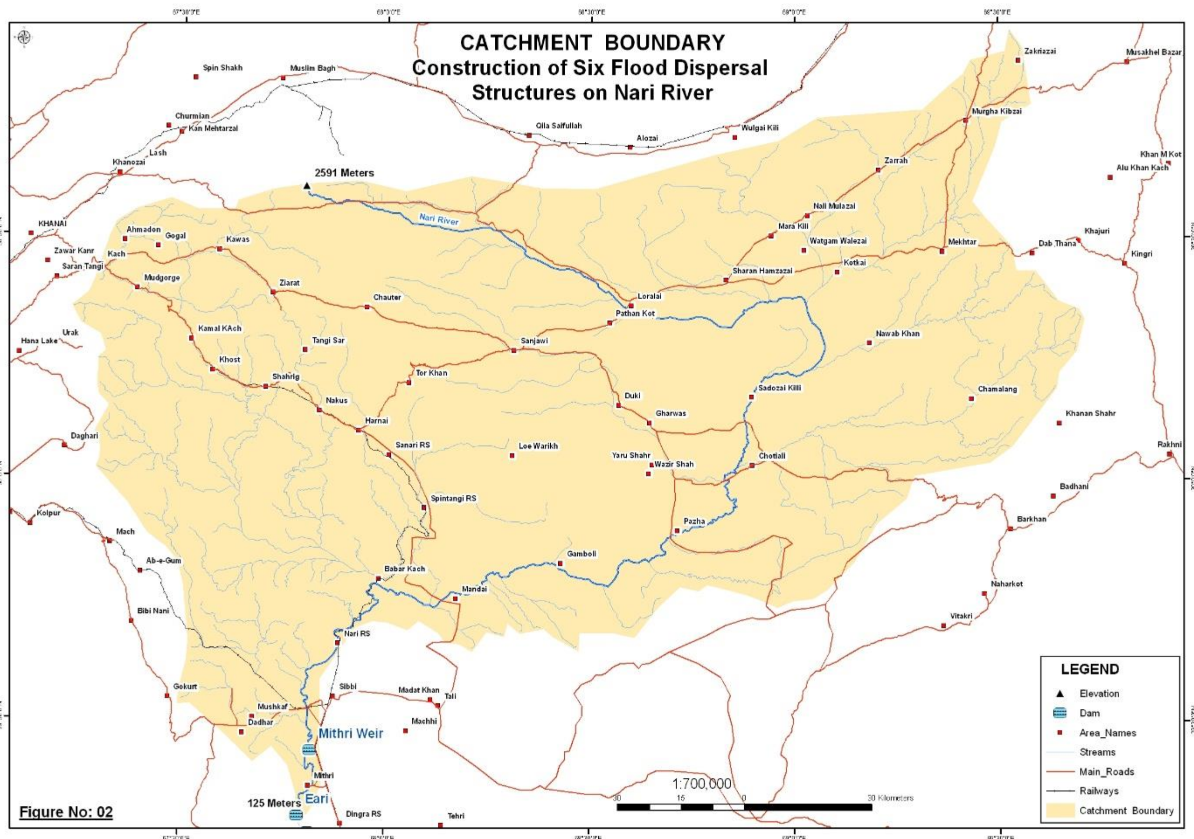
Dasgupta (2008) view, action initiation has its roots in the fear of weak capacity to mitigate climate change effects and curb depletion of natural capital in the future. A variety of arguments and comments made by economists apart from the ones made in traditional manner discuss the opportunity cost of capital and the discount rates that have great significance in the allocation of public resources. Political interests concerning the type of projects also come into view. Conventional practice of determining the economic value of large projects is highly sensitive to the employed discount rates. Large projects that require high investments are difficult to justify on the basis of typically used discounting rates. In general economist view, the social discount rates should remain below the 4 percent mark. On the contrary, international banks and government agencies used discount rates of 7-12 % upon the justification for accounting the opportunity cost of capital. In climate change discourse, there is a debate over the discounting rate of 3-4 %, which is considered to be considerably high.

1.4 Climate change Effects on Rivers Flow:

Globally climate is changing and societies doing adaptation to respond to these effects which they face because of these climatic changes. The uncertainties related to such changes are so high which cause difficulties for the government to where they should spend their investment or up to what extend the community or societies will be able to adapt towards changing climatic conditions? To reduce greenhouse gas emissions (GHG), what role should be played by government in aiding adaptation?

Whenever the issue of climate change come under discussions the basic issue of development arises that how we can take some initiatives to enhance the wellbeing of people. In Baluchistan the watersheds of Nari River covered many districts of Baluchistan. One question that increasingly rotate around concern over the growing issue of water scarcity. It is of the greater concerns for the policy makers and specialist in the Nari river Basin that how water resources can best advance greater societal development without providing any harm to the current users and about the practical implications of climatic changes for the river basin planning.

Figure 1: Watershed of Nari River:



Many previous studies indicate that Baluchistan is highly attractive location for the development of water storage infrastructures (Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008; Memon, Jogezai, Hussain, Alizai, & Baloch, 2017; van Steenbergen, 1997). The notable challenge for the planning process to confront is that arid and semi-arid developing countries (such as Pakistan) are particularly more vulnerable to climate change (M. Akhtar, N. Ahmad, & M. Booij, 2008a;

Oki & Kanae, 2006). New and existing infrastructures including Nari River and dam's plays important role in adaptation to climatic changes. But it depends on how they are sized and sequenced. This adaption is however, complicated by the fact that there is uncertainty factor involves, concerning how climate change will impact the region. Finally, since the Baluchistan province is already seeming highly constrained in term of water availability, or equal distribution among societies, the economic consequence of small change in water balance can be valuable. Bright et al. (2008) provide estimates of the impacts of climate change on weather elements mean daily river flows, irrigation water demand and water supply reliability for one catchment and associated irrigated area of Rangitata River in Canterbury. Projection for 2040 show that there will be one-degree increase in temperature with change in annual precipitation level increasing to 400 mm/year in the headwaters. There will be little change in the temperature level in the plains area. Potential evaporation in 2040 will increase by 60 mm/year in the plains area, but changes will be small in the Rangitata headwaters. Seasonal changes in the headwaters show a large increase in the precipitation level in winter and spring season. For plain area, there is no change in seasonal rainfall.

The research focuses on the various complex aspects relating to water resource planning that lead to tiresome effort in the calculating net benefits from new investment. This is due to uncertainties relating to climate change and future development prospects. Many challenges encompass the economic analysis, some being accurate estimation of future emissions levels and the changes that are result of greenhouse emissions. Furthermore, the impacts vary based upon regional settings. The water-development that is to occur in the future is uncertain and endogenous, which will interact with the climate change effects.

1.5 Climate change and planning of water resource investment:

Throughout the world climate change has a complex set of impact on water resource (Solomon, 2007). As we know GHG emissions is continuously rising which leads to increase in land temperature, precipitation patterns, water demand in agriculture, and the timing and magnitude of runoff, all of which will affect water resources systems (Frederick & Major, 1997; Parry et al., 2007)

When we discuss the change in water resource because of the climate change we observed these changes appearing at two levels. From economic point of view production process that requires those inputs (e.g. water) to produce will get affected. Like farmer’s land productivity depends on rainfall. Climate stressors (like drought, flood and temperature) can increase or decrease the productivity. In case of less rainfall the value of water will increase because of supply constraints. Consumption pattern of water resource will change. From physical point of view, the linkages are quite clear between climate stressors (such as temperature and precipitation) and hydrology of surface water. Change in temperature will affect the water demand in irrigated land and storage capacity of weir structures based on uncertainty about change in precipitation and discharge. If we see past trends of Baluchistan climatic conditions, from 1997 to 2005 they faced drought which increase the demand of water because of supply constraints and previously constructed dam reservoirs runoff level get affected because of low rainfall.

There has been substantial academic and practical progress demonstrating how these types of changes can be incorporated into hydrology models (Conway, 1996; De Wit & Stankiewicz, 2006; Frederick & Major, 1997; Van Dam, 2003). For the water resources analyst, there is much uncertainty associated with these types of hydrological and economic changes. Plus, current tools do not readily allow determination of which types of climate-related processes and uncertainties are significant for planning. Nor is it known how these compare with uncertainties related to other features of the development and investment problem. The longevity of investments in the water resources sector, the issue of forecasting such changes has long troubled planners.

1.6 The need for modified approach:

In order to overcome this issue, this research developed and demonstrates a hydro-economic modelling framework for integrating climate variability impacts into the planning problem of water resources. The two-level framework allows for simultaneous consideration of the types of physical and economic impacts described above. The first level relies on simulation of stream flows under different climatic conditions and incorporates linkages between climate factors and water withdrawal uncertainty. The second level then uses Monte Carlo simulation procedures to simulate the costs and benefits of the incremental changes obtained from the hydrological model, accounting for uncertainty about the value and productivity of the goods and services generated by the water system in question. A framework that allows testing of the sensitivity of project appraisal results to such fluctuations is valuable because it is difficult to make definitive statements about the physical and economic consequences of new projects.

This research thus goes beyond current approaches to water resources infrastructure planning, which often limit their focus to hydrological variability and treat economic costs and benefits as fixed parameters (or functions) within the valuation equations used to calculate the net benefits of new projects. Traditional approach of hydrological method, first developed at the Harvard Water Program i-e: Hufschmidt and Fiering (1966); Maass (1962) have proven extremely useful in water resources project appraisal. When the historical behaviour of the hydrological system can be assumed to be preserved, it is relatively easy to derive a project's expected (or lower and upper bound) net benefits, since its economic performance can be determined using tools that appropriately incorporate natural variability. Climate change has however motivated a timely rethinking of these methods, even though concerns over future uncertainty broadly defined have always applied (Lettenmaier, Wood, Palmer, Wood, & Stakhiv, 1999). The two level simulation frameworks are used in this research, and specifically for six dispersal structure project I will apply it, have the potential to offer insights for gauging the significance of this reassessment.

This research also argued that many aspects of the water resources planning problem lead to difficulty in the calculation of expected net benefits from new investments, because the probabilities associated with different climate and development futures cannot be easily determined. The difficulties with conducting traditional economic analysis emerge from several aspects of this problem, most notably that: a) accurate prediction of the future emissions levels that affect climate change is very difficult, especially when the possibility of mitigation exists; b) the ranges of changes caused by greenhouse gas emissions – physical and economic – are highly uncertain; c) the impacts themselves are likely to vary regionally and temporally in ways that are not well understood and/or predicted using climate models available today; and d) the future pattern of water-resources development within the same river is uncertain, endogenous, and likely to interact with climate change. The uncertainty that results from this combination of factors is not unlike the "unmeasurable, non-quantitative uncertainty" that Knight (1921) described in Risk, Uncertainty and Profit (1921).

1.7 A simple conceptual model:

Jeuland (2010) define the three knightian uncertainty[1] dimensions for riparian economies[2]. These three distinct dimensions of uncertainties are (1) climate uncertainties (scenarios) (2) Target water withdrawal condition (3) general economy uncertainty (states of the world). From these three, I conceptualize the first two uncertainties in this research for six dispersal structure project.

Climate Uncertainties: The first dimension of unmeasurable uncertainty we will consider has to do with climate change, and how it affects the economics of the project being evaluated. The effects of climate change are felt in the remainder of the system in three ways, via influences on 1) the physical behaviour of the water resources system; 2) the general economy in which the project is situated; 3) target water withdrawals. This climatic dimension of uncertainty will be considered to be exogenous to the water resources planning problem, in the sense that climate change occurs and the projects being implemented will not be considered to have feedback effects on it. Different possible climate conditions explored in this research will be referred to as climate scenarios.

[1] In economics we define knightian uncertainty as the risk that is immeasurable and not possible to calculate it. according to Knight, risk applies to situations where we do not know the outcome of a given situation, but can accurately measure the odds. Uncertainty, on the other hand, applies to situations where we cannot know all the information we need in order to set accurate odds in the first place.

[2]Riparian countries are those with water sources. Riparian means relating to or located on the banks of a river or stream. Jeuland (2010) used the 10 riparian countries of the Nile.

Figure 2: Three Dimensions of Unmeasurable Uncertainties:

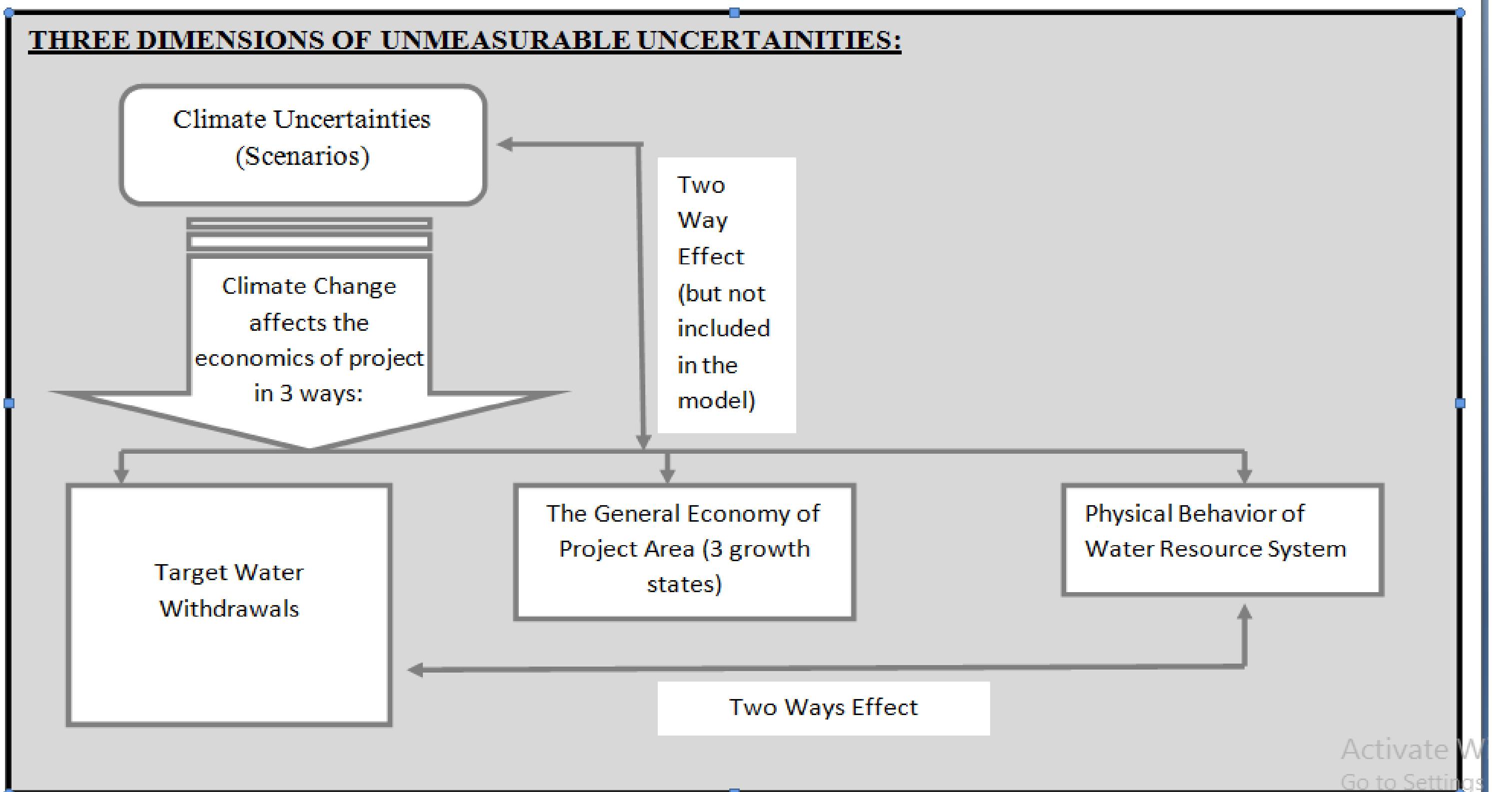


FIGURE 2: The three dimensions of unmeasurable uncertainty in the policy problem as conceptualized in this research. The first dimension are largely exogenous to the actions taken by community; these have to do with future climatic conditions. The second dimension has to do with the water withdrawals targeted by the

<u>Target water withdrawal:</u> Future withdrawal will influence by water demand and supply constraints. Water storage of Nari River depends on rainfall and flood. The storage capacity gets affected by climate change. For different climate stressor the discharge level change and capacity of water withdrawal affects. Future water demands will be influenced by population growth, economic development, technology, etc. Supply constraints will be affected by the water resource system's physical limitations and technology. One of the most challenging aspects of conducting policy analyses for the Nari river project is the fact that the target water withdrawal depends on climate stressors which can affect the physical system positively (flood) and negatively (drought). Furthermore, the changes in monsoon pattern also affect the system negatively and Baluchistan faced severe drought in past experience which put the feasibility of such dispersal structure in question. In this research, an illustrative set of changes in water storage and change in water usage will be termed target water withdrawal conditions.

1.8 A brief sketch for my decision analytical framework:

To demonstrate the difficulties that these two dimensions of uncertainty create for the water resources planner, I will use a set of decision-analytic criteria chosen to achieve a variety of different planning objectives. The objectives reflected in these metrics will be to reduce risks of negative NPV outcomes and to achieve better average economic outcomes. Their value will be calculated for six flood dispersal structure project under different climate scenarios and growth alternatives. Some of the measures will correspond to single individual climate scenarios and water withdrawal conditions. The advantages and disadvantages of the measures will then be discussed in the Nari River project context.

To be more specific, this study will show that the selection of the 'best' infrastructure development path is sensitive to two important considerations. First, infrastructure choices vary depending on the metric favoured by the planner. For example, a particular infrastructure, say a smaller dam/weir, or any other structure may involve less capital investment and therefore have a lower risk of negative outcomes, but it may also have lower expected NPV. Or, a dam or weir further downstream in the province may be less sensitive to natural hydrological variability and thus more robust to unfavourable NPV outcomes than a dam or weir far upstream, where the catchment is smaller and potentially more variable.

Second, the selection of the 'best' infrastructure will also be shown to depend on the planner's expectations of which future situation(s) is likely to be realized. In other words, even when applying the same decision-analytic metric to the economic outcomes for the project options, the choice of which one to favour will be shown to be sensitive to which situations are deemed plausible by the decision-maker. For example, two decision-makers using the same metric may prefer different options if one believes that climate change will certainly lead to reduced flows while the other believes that increased or decreased flows are both possible. Also, the extent of development in terms of water withdrawals and the number of projects constructed in the province alters the desirability of specific investments. Systematically studying how expectations of the future influences the choice of projects is useful for forward-looking planners, who may have well-defined priors about what is likely to happen.

Building on this analysis, and drawing from the literature on investment under uncertainty and "real options" (Dixit & Pindyck, 1994), I will develop relative measures for evaluating the performance of infrastructure alternatives. These measures will seek to account for the flexibility of infrastructure alternatives – in sequencing, operation, etc. For example, oversizing of infrastructures that could be feasibly operated at several levels may be justified if there is a possibility of increased future flows and high economic gains. I will argue that planners should collectively consider relative performance measures of downside risk, expected outcomes and upside potential across possible future conditions rather than simply relying on one of these dimensions. Using these metrics, three different investment strategies will be described. A "low-risk" strategy will be one which has the lowest potential for unfavourable NPV outcomes, looking across modelled situations. A "balanced" strategy will be one that demonstrates relatively high expected NPV while maintaining relatively low risks. Finally, a "high upside" strategy will be characterized by the greatest upside potential regardless of an option's downside risks. The details of this analysis will be presented in the later chapters of this dissertation.

For now, this research simply assert that the relative measures on which these investment strategies depend have several advantages: they provide information on 1) the nature of the risk 2) the expected costs of implementing low-risk, balanced, and high upside investment strategies varies across modelled situations; and 3) the expected costs (or reduction in risk) of delaying investments while waiting for more precise information about future conditions. I think policy-makers will find such comparisons of trade-offs to be useful.

1.9 Research problem statement:

Public projects by the Government always aim to provide benefits and relief to the people. But when such public projects are dealing with some natural resources like water, it need better assessment regarding the phenomenon on which the natural resource depends upon. In Pakistan, water projects like dams and weir structure are always controversial. It is whether because of the political conflicts or the assessment of the projects. Usually in Pakistan for all natural resource projects, Environmental Impact Assessment is carried out for the approval of the project. But that assessment does not fulfil the comprehensive requirement according to the uncertain climate future. As we know that natural resources directly depend upon natural climate conditions. And those conditions, having an uncertain future can affect the resource itself and thus the project dealing with that natural resource. Baluchistan dealing with water scarcity bear severe drought condition with a frequency of 4-5 years is dominant. Intense dry periods take heavy toll on livelihood patterns of the local population as irrigation and potable water resources run dry. Water availability is drastically reduced during extended droughts. Investing in new water infrastructure and rehabilitation of existing facilities are urgently needed to address critical state of agriculture, food security, and economic development in the province. Projects like weir structure aim to provide relief to the people of Baluchistan through healing the water scarcity problem. Projects aim to uplift the agriculture sector of the locality by providing water to irrigate lands for cultivation. But some major questions rise is that: what will be the value of the project under uncertain climate future? Climate stressors like drought or flood or changing monsoon pattern directly affect the discharge level of the river. If the extreme events are frequent in the expected future, will the project provide the desired outcomes? Whether the Government should spend in such projects dealing with the uncertain future and climate change or not? Climate impact assessment is necessary before implying such projects to know the real value of the projects under the climate change uncertainty.

1.10 Objectives of the study:

1) Generate the flow equation by applying maximum likelihood test, which shows the relationship between precipitation and runoff.
2) To develop future runoff of Nari River for time domain of 2017 to 2100 by using Representative Concentration pathways 4.5 & 8.5.
3) To analyse that the current and future water demand will be met by the generated flow in different climatic Scenario's.
4) Understanding climate hydrology of river system to better predict the effects of climate change on the physical output of water resource system and integrate the climate economic linkage with the physical result for analysing the factor that influence the value of weir structures.

1.11 Research question:

1) What distribution reflect the strong relationship between precipitation and runoff by applying Maximum likelihood test?

2) How future climatic conditions affect the discharge level for the time domain of 2017-2100 years?
3) In future climatic projection, Does the current and future water demand gets fulfilled or not? Either the Flow produce water surplus/deficit?
4) Under what climate conditions, if any, are the six flood dispersal structure projects likely to pass or fail a cost-benefit test?
5) What does the variation in performance of the proposed weir structures project across climate scenarios suggest about their relative value given uncertainty over future conditions?

1.12 Hypothesis of the study:

H_O; Precipitation is not significantly related with runoff

H_1; Precipitation is significantly related with runoff

H_O; Future climatic condition will have no effect on river discharge

H_1; Future climatic condition will have an effect on river discharge

H_O; Net present value of weir structure will not change with the change in growth state in the economy and with the change in discharge level.

H_1; Net present value of weir structure will change with the change in growth state in the economy and with the change in discharge level.

1.13 Significance of the study:

The proper procedure for social discounting of future costs and benefits of large public-sector projects has long been a contentious issue. Most economists argue that social discount rates should be below 4%, many international development banks and government planning agencies responsible for project appraisal can be found using rates of 7-12% or more. There has been long controversy among economist for selection of discount rate in case of public project which require huge upfront investment. So this research aimed at analysing a variety of discount rate to manipulate the net present value of public project under a variety of economic conditions. In this way we will able to provide guideline under what climate and growth situation which discount rate is feasible? I conceptualize a hydro-economic simulation framework for better analyse the effect of climate change on physical output of water resource system and integrate the climate economic linkage with the physical result for analysing the factor that influence the value of weir structure. This area has been studied through different ways, but specific to focusing on 3 dimension of knightian uncertainty are not yet considered specifically for Pakistan. This study contributes to literature by providing the procedure of how discounting should be done in climate uncertainties by analysing different discount rate under different growth states of economy which Pakistan has been faced in history. Furthermore, the study contributes in testing the changing value of Nari River project due to fluctuating discharge levels causing in result of climate stressor or changing monsoon pattern. Researcher around the world has used the Ramsey equation in their own different way for different purpose. M. Weitzman (2007) has used the Ramsey equation to evaluate which discount rate should be appropriate for social welfare. While Jeuland (2010) explained what discount rate should be appropriate within different states of economy under climate uncertainties. This research also aims to analyse the benefits specified in the project achieved or not for Baluchistan.

1.14 Plan of the study:

The study will be divided in different chapters; chapter one describes the introduction and conceptual framework of the study; second chapter will provide detailed description of six dispersal structure project. Third chapter will comprise the literature review. In the fourth chapter we explain methods and techniques applied in the study and how the framework has been operationalise. In fifth chapter we will present the results and discussion of the study before conclusion and then comes references of the study in the end.

CHAPTER 2: Case Study: Six Flood Dispersal Structures on Nari River, Baluchistan

2.1 Description of Study Site:

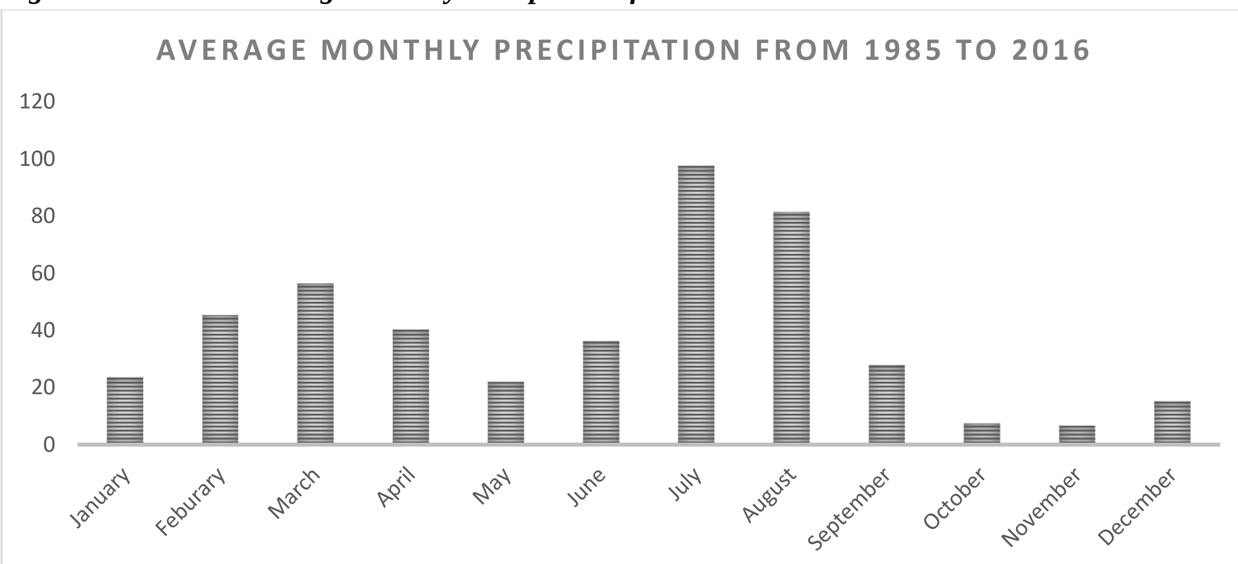
2.1.1 Watershed of Nari River:

The watershed of Nari River stretches between latitudes 29° 12' & 29° 53' N and longitudes 67° 14' & 67° 43' E. Nari River is the principal stream of the watershed which drains an area of about 22,525 sq. kms (8,700 sq miles). The Nari River originates near Spera Ragha and has a total length of about 400 kms (249 miles). The levels of the highest and lowest points are 2591m (8,50 .0 ft) and 125m (410 ft). The average slope of the river is about 0.62%. The River catchment is drained by various torrents which join to form medium sized runoff streams, ultimately combining to take the shape of Nari River. In the north eastern part, Loralai river and Sehan rud join together to form Anambar which, after receiving the flows from Narechi rud, assumes the shape of Beji river, a principal tributary of Nari River. In the north-western part of the basin, three streams namely the Loni, Sor Jhal and Loe Manda join to form Sangan River. Thus Beji from the east and the Sangan from the west meet near Babar Kach Railway Station to form the Nari River. Flowing further southward for about 4 kms, the river enters the Sibi Plain and splits into several meandering branches. Further downstream, these branches rejoin in the Kachhi Plain area where it becomes wide and shallow. Hereafter most of the discharge of the Nari River during floods is spilled over the banks at various locations and travels in the southern direction either as sheet flow or in meandering channels to strike the Patfeeder and Kirther canals, off-taking from Gudu Barrage.

2.1.2 Climate of Study area:

The climate of study area is classified as arid sub-tropical continental characterized by low rainfall. The mean annual precipitation of Nari River, Baluchistan ranging from about 200 to 231.68 mm (PMD, 2016). The rainfall is generally inconsistent and uncertain. About 65% of rainfall occurred in the monsoon period which is from June to July and during the winter, rain period that occurs during the months of February to April.

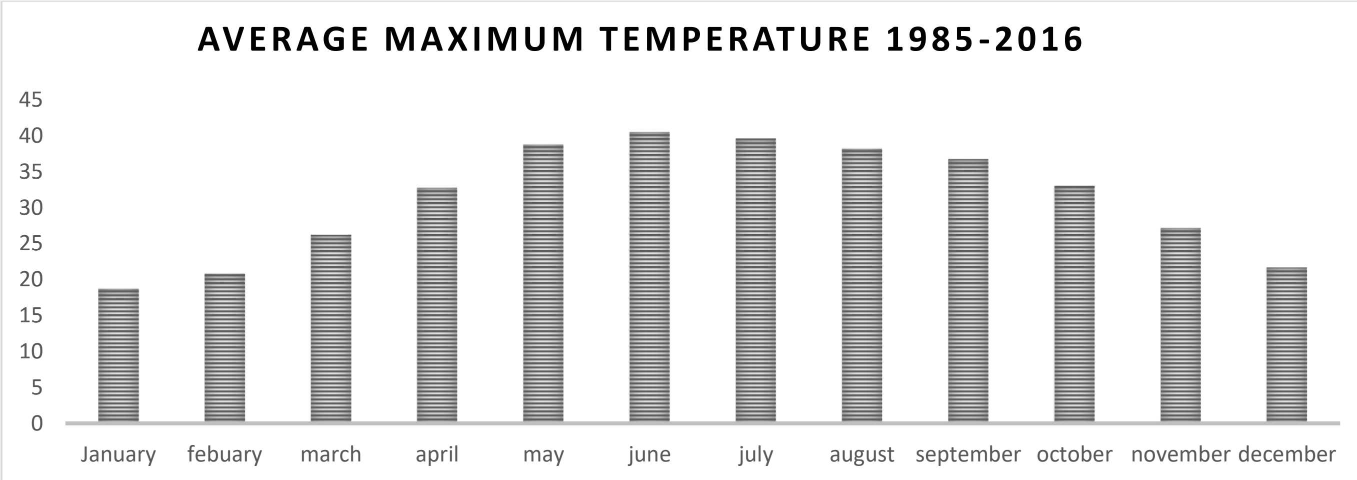
Figure 3: shows the Average Monthly Precipitation from 1985 to 2016



Source: Pakistan Meteorological Department, (PMD)

Summers are hot and winters are mild. June and July are the hottest month. The mean monthly temperature of June and July from 1985-2016 is about 39.6°C to 40.5°C. December and January are the coldest month with the average monthly temperature of 18.7°C to 21.6°C.

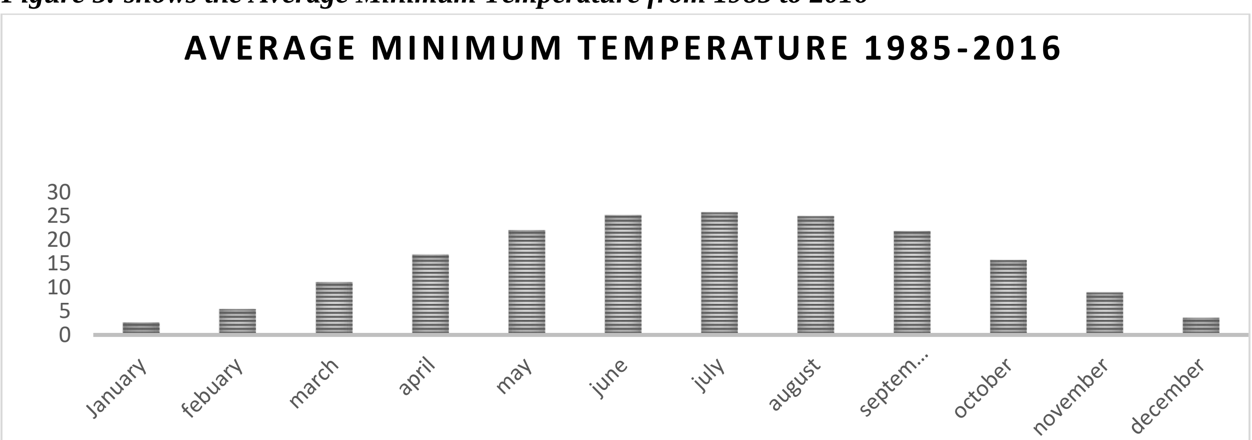
Figure 4: shows the Average Maximum Temperature from 1985 to 2016



Source: Pakistan Meteorological Department, (PMD)

This figure shows the average monthly minimum temperature for Nari river. The mean monthly minimum temperature of June and august from 1985-2016 is about 24.92°C to 25.72°C. December and January are the coldest month with the average monthly minimum temperature of 2.55°C to 3.55°C.

Figure 5: shows the Average Minimum Temperature from 1985 to 2016

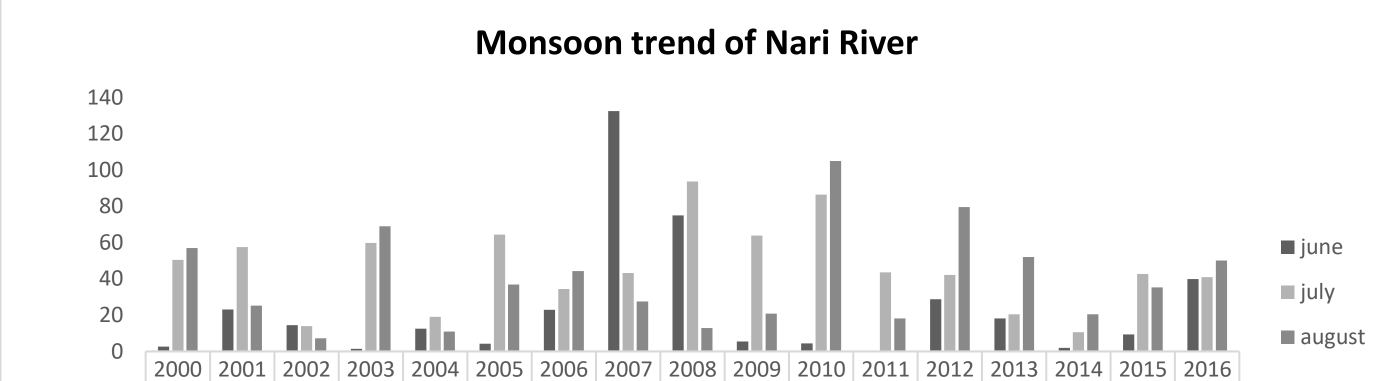


Source: Pakistan Meteorological Department, (PMD)

The region is home to natural and anthropogenic hostilities. Ranging from natural disaster such as floods, earthquakes and drought to political and social conflicts, Baluchistan is a complex region for study. These calamities have had an adverse impact on the sustainable development pattern of the region. Salma, Rehman, and Shah (2012) examined the rainfall patterns and prolonged droughts that will hamper the socio-economic development of the country. There will a great impact on agriculture and water management.

2.1.3 Monsoon Trends of Nari River:

Figure 6: shows the Monsoon trends of Nari River, Baluchistan from 2000 to 2016



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
june	2.7	23.15	14.5	1.5	12.6	4.3	23	132.6	75	5.45	4.5	0	28.8	18.1	2	9.35	39.85
july	50.5	57.55	14	59.75	19	64.35	34.4	43.3	93.65	63.95	86.5	43.55	42.1	20.5	10.55	42.7	41
august	56.9	25.3	7.3	69	11	36.8	44.35	27.5	12.85	20.75	105	18.1	79.5	52.05	20.5	35.25	50.05

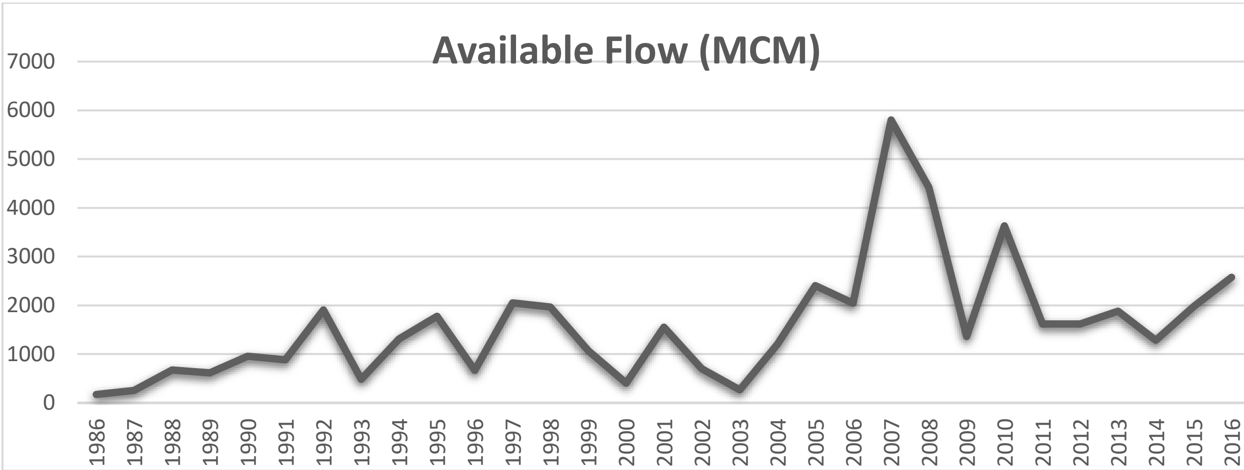
Source: Pakistan Meteorological Department, PMD

The table show the rainfall data for the monsoon season of Nari River for the past 16 years. Fluctuations can be witnessed in the monsoon season as 2007 is the year with highest monsoon precipitation and 2002, 2004, 2011, 2014 with the lowest values for precipitation in the monsoon season. Month wise, June is the month with lowest values in all the years whereas July and August show average precipitation in all the years.

2.1.4 Past Trends of Water Flow in Nari River:

A stream gauging station at Sibi bridge is available for a considerable period of time from 1961 to 1971 and then from 1986 to 2001. Based on the above the year-wise water availability of the Nari river basin is given as follows.

Figure 7: shows the Discharge of Nari River from 1985 to 2016



Source: Irrigation Department Baluchistan

Based on the above the wet (25%), average (50%) and dry year (75%) water availabilities have been estimated as 1029, 668 and 330.40 MCM respectively. The analysis of monthly data reveals that 82% of the flow will be available in Kharif season whereas the remaining 18% will be available during Rabi season.

2.1.5 Property Rights on River Flow:

Perennial flow is the right of district Sibi whereas the flood water is transferred to district Kachhi. Before the construction of the weirs, the community dependent on flood water (basically the people of distict Kacchi) constructed the mud structure blockade called (Gandas) in the local language and the cost of those Ganda's were borne by the Ghami community and when Ghami land was irrigated, water was transferred to Be-ghami people in the area. The shareholding or Ghami communities of each Ganda have well defined rights on flood water of Nari River. The upstream users at each Ganda divert the flood water till their irrigation requirements are met after which they let the water to the downstream users and this distribution pattern is repeated till the tail end of the system. Keeping in view the existing arrangement for water distribution, it is fair enough that each community should get share of flood water according to its land holdings.

2.2 Project Objectives:

Government of Baluchistan has recently approved the policy of Integrated Water Resources Management (IWRM). The policy specifically identifies the fact that the development potential lies on the surface water. With the development of surface water, able to meet the growing needs of various sub-sectors of water usage as well as to enhance groundwater recharge of depleted aquifers. Sailaba farming assigned the highest priority in the policy. Storage dams is constructed for the development of surface waters and to expand the command area and to recharge the groundwater. As we know that, agriculture places heaviest demand on the resource. The government strategy is to develop a clear vision for the future of irrigated agriculture in the province for the next 5 to 25 years. The Project after implementation will assist in conserving 287 MCM (232,596 Acre ft) of flood water. This flood water was used to irrigate about 36,854 hectares (91,030 acres) of fertile culturable land. The purpose of the Project is to disperse flood water for irrigating a vast tract of land located on the left and right banks of Nari River.

2.3 Cost of Project:

When PC-I Report is prepared and submitted for the approval to the federal government its original cost at that time is Rs. 3318.17 Million. But the PC- I report is approved at the reduced cost of Rs. 2000.167 Million. This amount is the 60% of the original PC-I report

2.3.1 Reasons of Revision:

Due to financial constraint the project is approved at reduced cost of Rs.2000.167 Million. With the reduction in cost the benefits of project also reduced[3]. As shown in table 2 that the construction of Khokar dispersal structure is removed. Also reduce some major works of Mithri weir structure and other structures. The reduction in cost from the original PC-I is Rs 1318.007 Million.

Table 2.1: Cost of Project at time of approval

S.No	Description	Original PC-I	Rationalized PC-I
		Amount (Rs. Million)	**Amount (Rs. Million)**
1	Mithri Weir System	769.938	330.997
2	Dispersal Structure at Erri	590.655	489.904
3	Dispersal Structure at Haji Sheher	505.362	407.724
4	Dispersal Structure at Tuk	338.236	282.529
5	Dispersal Structure at Ghazi	370.212	309.2
6	Dispersal Structure at Khokhar	274.811	------------
7	Residential and other infrastructure facilities	147.691	30.36
	Total:	**2998.905**	**1850.714**
8	Establishment of Project Implementation Unit (PIU)	73.479	54.207
9	Physical and Financial Contingencies	153.619	38.098
10	Construction Supervision and administration Cost	92.171	57.148
	Grand Total	**3318.174**	**2000.167**

Source: Irrigation Department Baluchistan

[3] Due to reducing the scope of work because of financial constraint the command area of cultural land is also reduced from 91,000 acres to 60,600 acres. The reduction on command area is 33%. Another issue that arise because of these reduction is the element of flood risk. Due to exclusion of road and other allied infrastructures the link of project site from other province could not be ensured during floods. There would be no access to the project components which might prove detrimental to the safety of the structures and the downstream communities in case of any catastrophe.

2.4 Aggregate Cost Analysis of Nari River Project:

Under the Six Flood Dispersal Structure Project, five Gundas are being constructed across Nari river at Erri, Haji Shaher, Tuk, Ghazi and Khokhar. The total cost incurred by ministry of water and power, government of Pakistan on the construction of five gunda's is Rs. 3,057.755 Million. With the construction of 5 gunda's investment of Rs. 1173.056 million is incurred on remodeling the Mithri Weir. The total cost of project including all expenditure is Rs. 4912.386 million.

Table 2.2: Capital cost/ Revised cost of Project:

S.No	Description	Amount (Rs. Million)
1	Rehabilitation of Mithri Weir System	1173.056
2	Construction of Dispersal Structure at Erri	764.588
3	Construction of Dispersal Structure at Haji Sheher	837.565
4	Construction of Dispersal Structure at Tuk	481.917
5	Construction of Dispersal Structure at Ghazi	500.182
6	Construction of Dispersal Structure at Khokhar	473.503
7	Provision of Residential and other infrastructure facilities	55.377
8	General Requirements and Facilities for Employer and Engineer	78.320
9	Establishment of Project Implementation Unit (PIU)	83.279
	Sub Total	**4447.787**
10	Physical and Financial Contingencies (2%)	88.956
11	Construction Supervision Cost (3%)	133.434
12	Price Escalation During Construction	242.210
	Grand Total	**4912.386**

Source: Irrigation Department Baluchistan

These revised cost include the most components of original PC-I.[4] They accommodate the requirements of protection bund upstream of the dispersal structures. They considered it important for the safety of the structures during flood in Nari River during operation. The Actual cost of project is almost doubled of the rationalized cost. With including all the previous components that has been deleted the cost increase from the original PC-I cost is up to Rs. 1594.212. The difference occurred or the cost is higher because of market price differential or higher contractor rates & revisions of designs.

2.5 Aggregate Benefit Analysis of Nari River Project:

Crop Area Assumptions: Crop area assumptions are appeared in Table 3 beneath. Existing crops are extended to make utilization of expanded water. The cropping example is somewhat basic as contrast with perennial irrigated plans. Grain, sorghum, corriander, guar and melon crops are created in with project circumstance.

Table 2.3: Crop Area Assumption: Increase in Crop Area after Full Development of project

Crop	Current		At Full Development	
	Hectares	Acres	Hectares	Acres
Rabi Crops				
Wheat	2024	5000	2733	6750
Barley	0	0	2077	5129
Guar	0	0	3047	7525
Kharif Crops				
Bajra	2105	5200	3036	7500
Sorghum	0	0	8441	20580
Mash	1619	4000	8300	20500
Corriander	0	0	2753	6800

[4] In revised PC-I they construct the black top road from the main Quetta D.M Jamali road to Mithri Weir in a total length of 1.85 kms. They also add the construction of Khokar Dispersal Structure which were removed previously because of financial constraint.

Melons	810	2000	3845	9496
Musk Melon	0	0	2733	6750
Total	**6559**	**16200**	**36964**	**91030**

Source: Irrigation Department Baluchistan

Crop Yield Assumptions: Yield rate suspicions are appeared in Table 4. The present yield is low, which depend on existing practice with no utilization of chemicals for splashing and chemical fertilizers as is generally normal for flood irrigated regions in Baluchistan. Yield projections in the Project situation have been made after due thought of the current yields of dynamic agriculturists and the yield capability of the region. Moreover, it is expected that a project contribution of augmentation guidance will significantly affect the production framework by the Agriculture Department.

Table 2.4: Crop Yield Assumption: Increase in production of various crop after full development of project:

Crop	**Initial Production**		**Production Full Development**	
	Hectares	**Acres**	**Hectares**	**Acres**
Rabi Crops				
Wheat	162	400	314	775
Barley	182	450	273	675
Guar	81	200	162	400
Kharif Crops				
Maize	1012	2500	2631	10500
Sorghum	121	300	1133	1500
Mash	40	100	2914	450
Corriander	0	0	161	400
Melons	607	1500	2429	6000
Musk Melon	607	1500	2328	5750

Source: Irrigation Department Baluchistan

2.6 Population of beneficiaries:

As explained above that the project aim is to increase the agricultural yield by providing equal distribution of water among communities according to their land size. Two types of beneficiaries prevail in the area. One is Be-Ghami community which is the indirect beneficiary because they hold no right on flood water but gets the surplus water. The other one is Ghami community.

Table 2.5: Total Population of Beneficiaries of Project (including Be-Ghami community)

Category	*Population*
Household's	2901
Beneficiaries	35,027

Source: Irrigation Department Baluchistan

2.7 Cost Benefit Analysis of Six Flood Dispersal Structures:

As explained above that the project split into two packages after the revision of PC report so they conduct the cost-benefit analysis of Package I and Package II individually. In package I the construction of Mithri Weir, Haji Sheher and Erri has been accomplished.

Table 2.6: Calculation of Cost-Benefit of Package-I

Cost Calculation		**Benefit Calculation**	
Package I			
Variables	**Cost (Rs. Million)**	**Variables**	**Benefit (Rs. Million)**
Scheme & land Development	2145.256	Existing Operation & maintenance Cost saved	0.737/year
Operation & Maintenance	10.726/year	New Output Agriculture	1055.245/year
Existing output Agriculture	42.471/year	Residual Value of Work	0

Source: Irrigation Department Baluchistan

In package II, the construction of Touk, Ghazi and Khokhar has been accomplished.

Table 2.7: Calculation of Cost-Benefit of Package-II

Cost Calculation		**Benefit Calculation**	
Package II			
Variables	**Cost (Rs. Million)**	**Variables**	**Benefit (Rs. Million)**
Scheme & land	1392.86	Existing Operation &	0.737

Development		maintenance Cost saved	
Operation & Maintenance	5.864	New Output Agriculture	605.94
Existing output Agriculture	22.027	Residual Value of Work	0

Source: Irrigation Department Baluchistan

2.8 Discount rate used in project evaluation:

In project, the IRR is estimated by entering the costs streams and benefits streams in columns of a spreadsheet, calculating the net cash flow and using the @ IRR function to calculate the IRR. The scheme benefits start in the year following construction so they did cost–benefit analysis for 50 years. It is assumed that the scheme continues at current production in the construction period and these benefits and costs are excluded from the IRR estimate as they balance. The FIRR is estimated at 16.50% and the ERR at 18.14%.

The Net Present Value at different discount rates has been calculated as follows.

Table 2.8: Discount rate used in Six Dispersal Project:

Net Present Value at different discount rates

Discount rate (%)	10	15	18
Net Present Value	2490	616	474
Benefit Cost Ratio	1.62	1.08	0.89

Source: Irrigation Department Baluchistan

CHAPTER 3: LITERATURE REVIEW

The literature review of the study consists some main aspects, those are: **a)** Water resource scenario, **b)** Factor affecting recharge and artificial recharge method, **c)** Dispersal Structures used for benefits, **d)** Climate change and water resource, **e)** Surface water and climate change, **f)** Monsoon and climate change, **g)** Rain Water Harvesting, **h)** Investment and planning in water resource **i)** Water resource evaluation of Weir structures, **j)** Economic assessment of water resource infrastructure with climatic and development uncertainty, **k)** Socioeconomic and environmental impacts of Weir Structures, **l)** Baluchistan climate projections, and **m)** Surface water effects on agriculture productivity.

3.1 Water resource scenario:

Water is one of the scarcest resources in the world nowadays and its scarcity is a major global concern. In many countries across the globe, freshwater scarcity is leading towards constraints in community's well-being and development(Oki & Kanae, 2006);(Rijsberman, 2006). The growing population of the world as expected, along with the economic development trends in the comings decades will push up the demand for water and thus worsen these issues (Vörösmarty, Green, Salisbury, & Lammers, 2000);(Arnell, van Vuuren, & Isaac, 2011);(Alcamo, Flörke, & Märker, 2007). Water demand can be fulfilled through availability of surface water which is in the shape of reservoirs, river, and lakes. But due to large regional and local variations, situation leads to water stress in many regions of the world including South Africa, Sahel, Central region of USA, Pakistan, India, North-East China, and Australia (Hanasaki, Inuzuka, Kanae, & Oki, 2010). The projection states that over 2 billion people which are almost 35% of the total world's population will feel the critical water stress (Alcamo, Henrichs, & Rösch, 2017). Ground water is commonly used as an additional source of water in regions where water stress is frequent. But if the abstraction of groundwater is exceeded the groundwater recharge, then persistent depletion and overexploitation can take place (Gleeson et al., 2010). The groundwater depletion results can have distressing effects on linked ecosystems, ground water fed wetlands, and natural stream flow. In coastal areas such groundwater depletion may cause salt water intrusion and land subsidence. The groundwater consumption is a serious issue in some regions of the world where the utilization of groundwater is (Van Steenbergen, 1995). Moreover, groundwater is the world's most mined resource (UNESCO, 2003);(Mukherjee et al., 2015). The utilization of groundwater over the recent decades has developed rapidly leading towards consumption of aquifers and contamination of groundwater (Giordano, 2009);(Wada et al., 2010). van Steenbergen (1997) working on such groundwater issue in Baluchistan concluded aquifer in Kuchlagh region was depleted due to the excessive use and extraction of water for agriculture through tube wells. The number of tube wells was as large as more than 300 wells. Unsustainable and unusual use of resource is normally expected that would lead to trouble. In Kuchlagh, lack of team work or collaboration procedure along with lack of technical efficiency for the utilization of water resource was the main causes of the curse. Such scenario is a perfect example of socio-institutional ineffectiveness where no timely measures are taken thus the resource is slowly depleted. According to the assessment, almost 1 MAF of total potential available, about 0.5 MAF by this time is being consumed, which means that 0.4 MAF is still available for utilization. This situation can also create misconception, because of the dependency of aquifers on topographic conditions. It is also noted that groundwater is being overexploited in Nari and Pishin Lora which is an alarming situation in the long term as it may create mining conditions and will make the aquifers dry which is threatening to livelihood (Kahlown & Majeed, 2004). The usage of groundwater has exceeded by 22 percent to its recharge in the semi-arid areas of Baluchistan (Halcrow, 2007).

3.2 Factors affecting recharge and Artificial recharge method:

Surface water and groundwater are main source of fresh water in Pakistan. The great freshwater aquifers of Indus plains are recharged mainly from rainfall, distributaries, waterway streams, and flooded fields (Kahlown & Majeed, 2004). Groundwater aquifers in the Indus Basin can be extracted to beneficial use and big agriculture returns can be attained by extracting the water of the predominant recharge. But it will result in further fall of water table and issues like underground water depletion (Kahlown & Majeed, 2004).

In Baluchistan, the recharge of groundwater is being affected due to various reasons. Area witnessed two development stages from the 1970s onwards that changed the economy of local scale. First variation was the extended population pressure due to the afghan refugees after Afghan-Russia war which put burden on the resources. The second variation was the rising trend of the profitable apple cultivation. This caused a sudden increase in the exploitation of groundwater. Initially in the 1970s, dug wells were introduced and the water tables fell down and the springs and karezes on which could be relied upon, went beyond the level. In the late 1970s and early 1980s, more dug wells were developed by the ones who could afford it due to strength loosening karezes. Eventually, the dug wells failed because of over extraction of groundwater and spring boxes were fitted inside these dug wells. The Situation continued to be threatening and the groundwater table continued to fall. In 1990s, dug wells were replaced by deep electrical tube wells which required submersible pump to function (Van Steenbergen, 1995);(Mustafa & Qazi, 2007);(Baloch & Tanık, 2008). Technical Paper of Intergovernmental Panel on Climate change (IPCC) on water assesses that, during the last 30 to 40 years, groundwater levels of plenty of aquifers around the globe are showing the decreasing trend. And this decreasing trend has nothing to do with climate variability but it is due to rapid extraction rate of groundwater. Various measures are being taken to tackle the issue of groundwater depletion, including percolation basins, delay action dams, diversion structures, furrows, ditches, injection wells, and modified streambeds. Whereas, the implementation of these measures totally depend upon the local environmental and topographic conditions.

3.3 Climate change and water resource:

Increasing water demand by massive population and the variability in climatic conditions put extra pressure on world's water resources. Many of the scientist through their respective methods of forecasts and projections mainly thorough global climate models have indicated that the world may face water stress in the future(Oki & Kanae, 2006);(Alcamo et al., 2007);(Arnell et al., 2011);(Gosling & Arnell, 2016). Research on various aspects of climatic variability is taking place at an increasing pace and water resource cannot be excluded from this. According to intergovernmental panel on climate change (IPCC), climatic variability has a complex set of impacts on water resources throughout the world (IPCC, 2007). Due to increased concentration of greenhouse gases, rainfall patterns have change, surface and ocean temperature and evapotranspiration rates have risen, intensity and frequency of catastrophic events have increased, the magnitude and timing of runoff has affected, sea level has risen, agriculture production has affected as irrigation demands have altered. Climate change is affecting and will affect almost all regions of the globe mainly through surface and groundwater depletion (Stocker, 2014).

However, the intensity of the impacts may vary from country to country depending upon the topographic features which make them vulnerable. But some of the biggest water resource regions may face water shortage which include South Asia, where the population density is higher, that put extra pressure on water resources. Thus massive population of the world is under threat of water scarcity. The intensity and frequency of water related catastrophes i-e: droughts and floods may likely to increase all over the world, that will affect the agriculture sector heavily. In order to tackle the issue of water scarcity, it is important to plan for the future water resource conservation strategies in the context of climatic variability through temporal and spatial techniques.

There are many components of water balance in the context of climate change discussed in the existing literature of those some are: ground water recharge (Scibek & Allen, 2006), stream flow (Fu, Chiew, Charles, & Mpelasoka, 2011), evapotranspiration (Calanca, Roesch, Jasper, & Wild, 2006), runoff (Nunes, Seixas, Keizer, & Ferreira, 2009), extreme events (Xiong, Feng, Hu, Wan, & Yang, 2009), a particular extreme event (Cuo, Lettenmaier, Alberti, & Richey, 2009), seasonal process shifts (Thomas, Twyman, Osbahr, & Hewitson, 2007). A very few scientists however have emphasized on the impacts of climate change on regional hydrological process regarding long run projections. But this may be the most important dimension to cover as hydro-climatology can help in water resource management and planning. In order to take out the net effect of climatic variability on water resource, an integrated hydrological simulation model may be useful (Serrat-Capdevila et al., 2007).

Changes in rainfall patterns are being witnessed due to climatic variation which poses marginal threat to water security as the supply of water in many regions may see drastic changes (Fung, Lopez, & New, 2011; Hagemann et al., 2013; Vörösmarty et al., 2000)(Vörösmarty et al., 2000).

However, the impact of climatic variability on water resources is unclear due to plenty of reasons. The projection models commonly used are inconsistent to the regional level as those are projected at average global changes. This cause biasness regarding the magnitude or the signs when analyzing it for the regional level, specifically for precipitation (Meehl et al., 2007). There are certain parameters which may be included in order to find out the impact of climate change on water resources in a regional perspective, those include: soil properties of the area, vegetation cover, and topography. These parameters are though included in the hydrological models with name of 2nd level of uncertainty (Hagemann et al., 2013).

3.4 Surface water and climate change:

Climate change will bring changes in hydrological parameters like temperature, evapotranspiration (Jain & Kumar, 2012). These parameters are very common when we observe all other variables like humidity, pressure etc. when we analyze the impact of climate change on hydrology of water resource in the future at global and regional scale we made projection regarding the parameters trends. These projections seem important and helpful in analyzing the impacts. As the water resources are inextricably linked with climate, the global Climate Change has serious implications on them (Bates, 2009). Therefore, it leads to the vulnerable state of water resource worldwide. Hydrological cycle has been altered by warmer climate change. The magnitude and nature of discharge for various river basins has changed across the world. The changing temperature and precipitation conditions are key drivers to the changing climate conditions (Mall, Gupta, Singh, Singh, & Rathore, 2006). This research focused on surface water which includes the Nari River on which the livelihood of many people's depending upon. Surface water provide habitat to many animal and plant species. Surface water is easily developed for use because it is on land surface. Stream flows depends on climate and the action of human activities and climate affect those flows. Akhtar et al. (2008a) in his research stated that precipitation and discharge gets highly affected by global climate change. They observe large change in water supplies in arid and semi-arid region due to moderate change in precipitation. Highest temperature in mountainous watersheds will positively affect the ratio of rain to snow, hasten the rate of spring snowmelt, and shorten the overall snowfall season, leading to more rapid, earlier, and greater spring discharge. Surface water demand is tremendously increasing in Pakistan. Reason of such increase is growth in agriculture sector and the population. It contributes almost 40-50% of the crop water requirement. In sweet water zone areas, the domestic and industrial requirements are met by ground water. However, in saline groundwater areas the domestic and industrial requirement is met by the river supplies (Haq et al., 2015). Surface water development is critically important under such circumstances where trans-boundary water disputes are common doubled with the issue of climate change that poses extra pressure in the shape of frequent and more intense climate stressors like floods and droughts (Haq et al., 2015). The frequency and the magnitude of the extreme events is higher due to climate induced factors and changes in the hydrological system. And such climate induced variations cause massive social and economic loss to mankind. Extreme events such as floods may become more frequent, destructive, and intense in the future (M. Akhtar, N. Ahmad, & M. J. Booij, 2008b). The emerging body of knowledge on climate change which is more evident and clear than ever, will add a new set of challenges which will require a proper knowledge, on-time management and planning initiatives.

When talking about an integrated water system, surface water holds a key importance in the net availability of water. Surface water is of great significance to the agriculture sector of an economy. But due to prevailing conflicts on surface water and changing precipitation patterns which causes water stress, target demands cannot be achieved in agriculture sector (Habib, 2004).

3.5 Monsoon and climate change:

When it comes to the regional analysis of water scenario, the impact of climatic variability on monsoon is uncertain and prediction becomes difficult (Akhtar et al., 2008a). Pakistan's climate is arid and semi-arid in most of the parts with significant temporal and spatial changes in climate parameters. More than half of annual rainfall is due to monsoon rains, which is a dominant source of water recharge for Pakistan. But according to Chaudhry (2010), the monsoon duration for Pakistan is lower than the other regions which come under the same monsoon command area. This is because of the location Pakistan holds, which is the edge of the western end of south-western monsoon. The duration of monsoon that Pakistan receive is about 1 and a half months. The heavy precipitation events ranges to an average about 100 to 120 mm per day, but the south eastern part of the country receives low rainfall in comparison to the northern parts of the country (Khan, 2013). The interfaces and the interconnectivities of monsoonal climate with the occurrences of extreme weather events, temporal and spatial variation in rainfall, shared river systems, predominance of agriculture, increase in human population demands a continued collaboration among different stakeholders / states / disciplines with respect to water security and climate change (Bhatt & Mall, 2015).

3.6 Rain water Harvesting:

For centuries, rainwater harvesting is being used as a common practice. The use of this practice is of great importance in many developing countries of the world due to increasing water scarcity. There is no doubt that the technique is of great significance to the rural parts of world as agriculture practices commonly done in those parts, but the use of this method is also suitable and necessary for the urban parts as well. Specially in the areas where traditional supply sources are limited or distant.

Small isolated communities in the mountain areas use several novel techniques to store rainwater for domestic as well as agricultural uses. A few documented examples of water harvesting methods developed for agricultural purposes, in the mountain regions are; diversion system and the dam system. Under the diversion system, a long channel diverts the floodwater to cultivation areas adjacent to the valleys. Under the dam system, a large reservoir behind the dam is filled with floodwater.

In Baluchistan, which is the south-western province of Pakistan, rain water harvesting is the major source of irrigation because of the fact that the region is completely rain-fed. Different methods are used for harvesting which include: building blockade structure to a flow of stream or flood water during rainy season commonly known as bunds. This method of harvesting is known as Sailaba system. Another system which is common in Baluchistan is the Khushkaba system of rain water harvesting, in which the catchment area is fetched on the upper side of the farms and the water is utilized in the farms commonly on the lower side of the catchment area through building channels to the water (Tariq & Van de Giesen, 2012)

3.7 Investment and planning in water resource:

Investments in water is amongst one of the major priorities of government at different levels and different institutions, but when the decision making is concerned, a split and conflict is witnessed at different levels. When the water is used for productive purposes, it is covered by the relevant ministries such as: power and energy, and agriculture, but the authority or hold over this is not their concern. That is whether the concern of the parliamentary forces or non-parliamentary political forces which influence the decision making in this regard. A multiple criteria environment is a necessary measure for management and planning of water resources. These multiple criteria for decision making process (MCDM) methods are used in numerous studies, some of those include: (Duckstein & Opricovic, 1980), for waste water management (Simonovic, 1989), for extreme floods (Duckstein, Treichel, & Magnouni, 1994), for river basins (Tecle, Fogel, & Duckstein, 1988), for groundwater management (Abrishamchi, Ebrahimian, Tajrishi, & Mariño, 2005), and for agricultural development (Abrishamchi et al., 2005). The implementation of this MCDM criteria show that this is a well suited method to apply for water resources management as an efficient tool for decision making.

A major gap which lies in water management issues and is a problem as well is between the theory and its practical implementation due to a complex environment of system dealing with it. As argued by different authors mainly: Duckstein, Netto, and Parent (1996), the planning and management problems in water resources are: a) in a complex objective space, a demand for multi-dimensional goals b) degree of uncertainty c) a traditional structure of alternative options for solutions combined with complex actions for various time horizons i-e, short term, medium term, and long term.

In order to attain social well-being and economic growth, financing in water security is a requirement. As almost all economic activities depend upon the development and management of water resources and adequate supply of water. Investment in water is meant investment in country's social development and economic improvement.

In Pakistan a very few studies are found who worked on water resources, in those one of the important studies is of Ahmed, Iftikhar, and Chaudhry (2007), they analyzed the in-depth water conservation strategies for Pakistan. The conclusion of their study was that practice used for water resources in Pakistan are not according to the requirements of conservation. And there is a need for integrated conservation approach and to analyze the water resources of Pakistan, in order to meet the need of future water requirements.

3.8 Prediction of Discharge from River:

For planning and management, the climate and the hydrological modellers have begun working out runoff projections. During recent years, the Global Climate Models (GCMs) and Regional Climate Models (RCMs) driven hydrological models are in frequent use to draw such projections. But the projections have been often found to lack of reliability. Very recently, there is another emerging field of multi-model ensembles that has added feather to cap of the climate modelling community but this field is yet to be tried in many of the basin runoff-studies especially in the Indian perspective. There is a dire need for more research input assessing the future runoff as far as the Pakistan's River basins are concerned. The climate models are being improved day by day so are the hydrological models. The multi-model ensembles are expected to bring out more reliability in the model outputs regarding the future runoff regimes of the basins than that could be brought about using individual models.(Bhatt & Mall, 2015)

3.9 Economic assessment of water resource infrastructure in context of climatic and development uncertainty:

In the past many economists did research on economic assessment of water resource. We all know that future is uncertain and we have no information on future climate conditions. Many economists try to remove the uncertainty by developing various climatic scenarios under which they provide information on how to conduct an economic analysis of water resource by removing uncertainty for developed countries. Ashraf Vaghefi, Mousavi, Abbaspour, Srinivasan, and Yang (2014) conducted a research in which they integrate a hydrological Soil and Water Assessment Tool(SWAT) model for Iran for analysing the large climatic variability and its impact on water resource. Their finding reveals very interesting fact wet region receive more rainfall then dry but when develop various climate scenario the result is quite different. Jeuland (2010) conducted his research on how to do a planning in water resource by analysing the knightian uncertainties for riparian economy. This is the first research who took uncertainties into account for water resource assessment. The analysis showed that: 1) many projects provide positive net benefits across a range of conditions; 2) increased system water withdrawals have a significant negative impact on the economics of Blue Nile dams; and 3) results are most sensitive to assumptions about discounting and future inflows. Also, the infrastructure with the best economic outcomes is dependent on the unknown future climate of and water use in the system. An approach was therefore developed for comparing the relative performance of alternatives, and comparative metrics were used to identify alternatives with relatively low risks and high upside across a range of plausible future situations.

3.10 Surface water effects on agriculture productivity:

In Pakistan its importance is more than ordinary due to the agrarian nature of the economy. The share of agricultural sector in the Gross Domestic Product (GDP) of Pakistan is about 24 % and generating over 70% of total foreign exchange earnings of Pakistan. Since agriculture is the major user of water, therefore sustainability of agriculture depends on the timely and adequate availability of water (Kahlown & Majeed, 2003). In 10 out of 19 sub-basins groundwater use is overused. The Pishin Lora – of which Kuchlagh is part – accounts for the largest imbalance with consumption a factor 4 higher than recharge. Almost all use is for agriculture. What happened in Kuchlagh may be representative for other areas in Baluchistan in the future as well as for other semi-arid are as dependent on groundwater for agriculture. The aquifer was depleted (Van Steenbergen, 1995). Agriculture sector uses 97% of the water in Baluchistan (Khair, Mushtaq, & Reardon-Smith, 2015).

When river flow is variable, then storage is required so that the supply of water can more closely match water demands. Relative to other arid countries, Pakistan has very little water storage capacity that whereas the United States and Australia have over 5000 cubic meters of storage capacity per inhabitant, and China has 2200 cubic meters, Pakistan has only 150 cubic meters of storage capacity per capita. As a result of this constraint, the water availability during the crucial Rabi maturing and Kharif sowing seriously hampers the system capacity to meet the irrigation requirements which translates into lower yields (Haq et al., 2015).

CHAPTER 4: METHODOLOGY OF THE STUDY

4.1 Operationalizing the Framework for water resource project planning problem:

In this chapter, the specific methods and models used to make the evaluation framework operational for evaluating the costs and benefits of the Nari River weir structures project are discussed in more detail. The operational version of the framework is composed of twelve steps. Steps 1 through 7 are within the hydrological level of the framework, and steps 8 through 12 are in its economic level. For the purposes of exposition, the presentation below assumes that climate change and water withdrawal is the only dimension of "unmeasurable" uncertainty reflected in the modelled situations. The extension of this procedure over other uncertain dimensions is straightforward and requires additional repetition of the procedure. For example, if one were interested in studying the infrastructures in multiple withdrawal conditions, one would simply repeat the entire procedure in steps 1 through 12 for each such condition. The steps are:

Physical:

1. a) Definition of climate scenarios b) selection of a single scenario

2. Specification of the linkages between the climate scenario and the water resources system;

3. Generation or choice of inflows corresponding to the runoff in the selected climate scenario;

4. By using the Flow equation, a runoff series will be generated for each climatic scenarios

5. Define water withdrawal condition

6. Select one withdrawal condition with each climatic scenarios, repeatedly to show water balance in each situation

7. Cataloguing of the physical measures of the project's incremental effect on the system;

Economic:

8. For Monte carlo simulation, the first step is to develop the model logic. This is computed in financial model first. This is the starting point of @risk analyses.

- The value, we are interesting in analysing our bottom line will become the output cells in @ risk; Define output cell (which is NPV in our case)
- The values that are uncertain will become the input cells in @Risk; define economic and hydrological cost and benefit parameters.

9. Designate the @Risk output cells; by doing this it will add the risk element with each of the output cell.[5]

10. Define input distributions, in this step we define the probability distribution of each of the @risk input cells/uncertain inputs. There are many different probability distributions which we can use in @risk inputs. Here we use uniform, normal & triangular distribution.

11. Change the number of iterations; when we designate the output cells and have entered the probability distribution for input cells, before running simulation we set the number of iterations. This means how many random scenarios you want @risk to generate. The more iterations we used, the more accurate our results would be. We choose 10000 iterations.

12. a) Simulation and b) storage of economic measures for the given climate scenario and water withdrawal condition, using a Monte Carlo economic simulation model;

Selection of the next climate scenario, and/or water withdrawal condition, repetition of steps 1-12; and

13 Analysis of results and evaluation of the project alternatives across climate scenarios with the aid of decision rules.

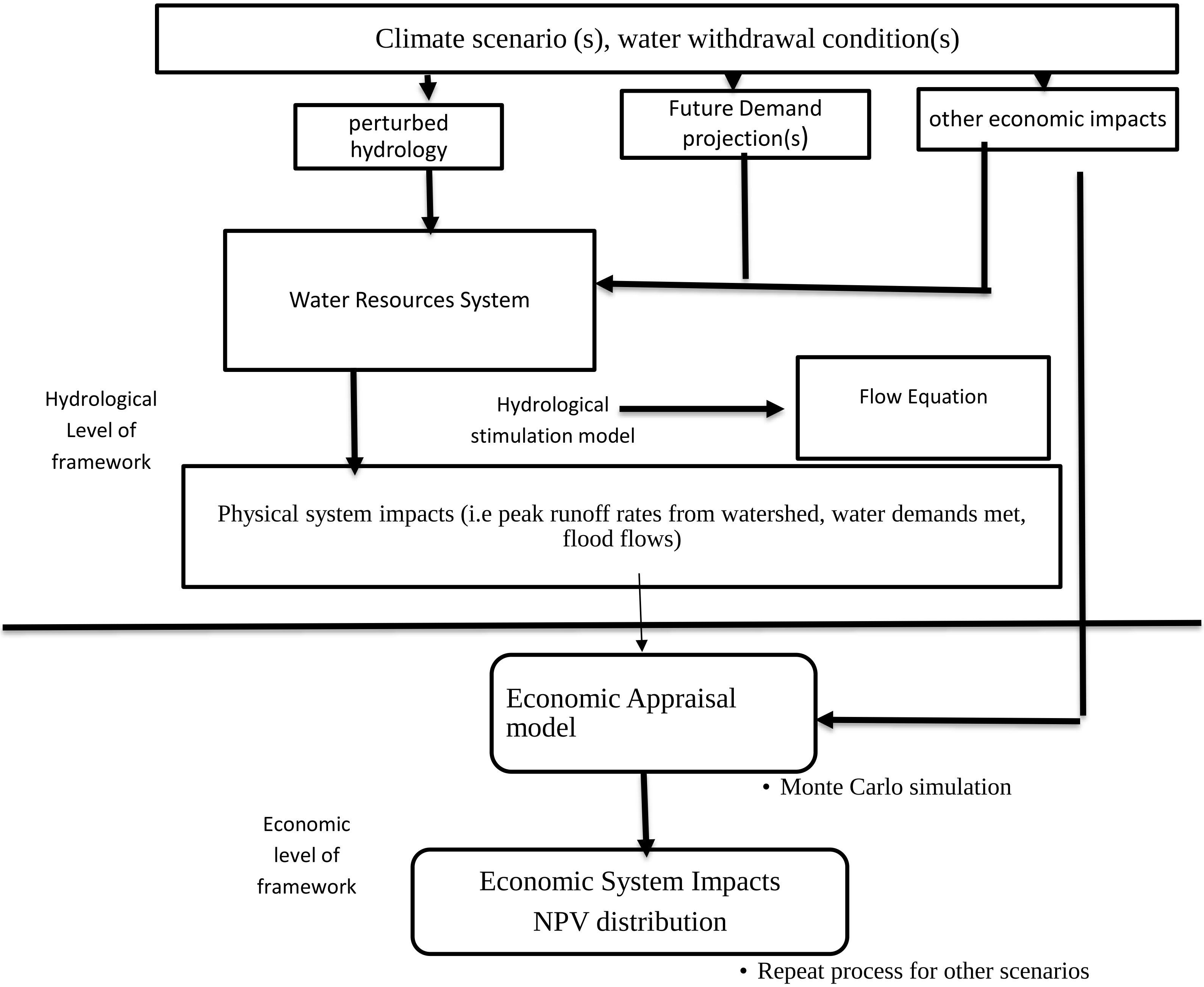
[55] @Risk won't tell you exactly or certain values for these outputs. This is impossible because the future cannot be predicted with certainty. But in result section it will be shown @risk can report the probability of different values incurs for each output and that information can help us to make more important decisions.

4.2 The Integrated Hydro-Economic simulation framework:

The use of repeated simulation in any project evaluation in line with the uncertainty challenges and possible states of the world may provide latest insight. The conceptual framework introduced in Chapter 1 of this research would be applied across a series of possible climate scenarios and water withdrawal conditions. Such framework could be utilized to check the impact of climate and natural variability on physical system, moreover the uncertainties regarding the economic side related with the change in physical system and the physical output value extracted from it. The framework map is shown in figure 8, which provides a quick review. Firstly, water withdrawal condition and climate scenario will be selected. Secondly, flow equation will be generated for different scenarios to acquire run off which would further analyze the production and water balance water balance based on different scenarios. Thirdly, economic simulations will be conducted using or developing a specific tool which will incorporate the economic and physical uncertainties related to climate variability.

4.3 Methodological Flow Chart:

Figure 8: A modified simulation framework for economic appraisal of water resources investments, showing the two levels (hydrological and economic)



It will provide us the modified analytical approach for stimulating the economic performance of new project in a variety of possible future situation.

Methodology of this research is based on two segments; a) the physical aspects b) The economics aspects.

4.3.1 Physical Aspects:

For generation of projected runoff under RCP 4.5 and 8.5 we need a flow equation that shows a relationship between precipitation and runoff. Because the data of projection shows a monthly precipitation (in mm) for 2100 years of Nari River catchment area. The relationship equation is determined by using the historical data[6]. We apply maximum likelihood test.

Generated Flow equation that is used to estimate the projected runoff for different climatic scenarios:

$$Flow\ (MCM)\ =\ -196.91795 + 3.85914 * annual\ precipitation\ (mm)$$

4.3.2 Economic Aspects:

We will use Monte Carlo simulation technique to stimulate the NPV (net present value) of project with the given variation in economic model parameters. This strategy initially created at Harvard Water program (see for instance Maass et al. (1962) and Hufschmidt and Fiering (1966) have demonstrated to a great degree valuable in water resources project appraisal. Economic model parameters that will be used in this technique are cost, benefit, discount rate, planning horizon, discharge and water withdrawal situations.

[6] Further detail of how it is done are given in results section

When flow equation is determined and we will able to generate the runoff in different climatic scenarios. We need to analyse the impact on economic model parameters to get economic outcomes. The benefits of project is based on agriculture production as described in chapter 2. In below section I have provided the detail how change in runoff affects the revenue of project under different withdrawal condition.

In order to take out the monetary value of the benefits from the project. It is assumed that the water is fully utilized in agriculture production i.e------cusecs/or any unit. Although in actual scenarios the utilization is not limited to agriculture production, as water is used for raising livestock and drinking and domestic purposes. But those uses cannot be reflected in monetary terms. Therefore, full utilization of water scenario is set for crop production.

In order to avoid complex calculation of land use for multi crops, two main crops were taken for estimation i.e wheat and sorghum. Both the crops are the most commonly grown crops in the study area and are the major cash crops of Barani areas. And for these two crops, we have the full information of crops growing requirements and the current rate at which the crop can be produced and sold in the market.

Monetary value of crops is extracted on the following conditions: (1) water is fully utilized according to current crop water requirement (taken from FAO), (2) crop production technology remain same e.g seed rate per acre, labor and capital used per acre etc. (3) land use pattern is according to the taken crops i.e wheat and sorghum, (4) prices of inputs and outputs remains constant i.e current and existing prices of 2016 and 2017 (January and February).

The production functions for growing wheat and sorghum are given as under (following the above mentioned limitation).

$$Wheat\ (f) = land\ used + seeds\ per\ acre + fertilizer\ used\ per\ acre + water\ used\ per\ acre + labor\ per\ acre + capita\ per\ acre$$

$$Sorghum\ (f) = land\ used + seeds\ per\ acre + fertilizer\ used\ per\ acre + water\ used\ per\ acre + labor\ per\ acre + capita\ per\ acre$$

A data series of generated revenues under different climatic scenarios and water withdrawals condition are given in appendix. And we will use the revenue in economic simulation because it is one of the economic model parameter. we will discuss this in later chapters as well.

Monte Carlo Simulation: Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making. Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities—the outcomes of going for broke and for the most conservative decision—along with all possible consequences for middle-of-the-road decisions. We selected this technique because risk analysis is part of every decision we make. We are constantly faced with uncertainty, ambiguity, and variability. And even though we have unprecedented access to information, we can't accurately predict the future. Monte Carlo simulation (also known as the Monte Carlo Method) lets you see all the possible outcomes of your decisions and assess the impact of risk, allowing for better decision making under uncertainty.

Monte Carlo Simulation technique:

NPV = f (± Discount rate ± Discharge Level ± climate uncertainties)

Net Present Value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from the project. The formula for the discounted sum of all cash flows can be rewritten as

$$NPV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

NPV is a dependent Variable that depends on number of uncertainties that are itself interlinked with each other. (Description given in conceptual framework)

DR = discount rate (2, 4, 6, 8)

When we focus on the debate on discounting controversy. Conventional practice of determining the economic value of large projects is highly sensitive to the employed discount rates. Large projects that require high investments are difficult to justify on the basis of typically used discounting rates. In general economist view, the social discount rates should remain below the 4 percent mark. On the contrary, international banks and government agencies used discount rates of 7-12 % upon the justification for accounting the opportunity cost of capital. In climate change discourse, there is a debate over the discounting rate of 3-4 %, which is considered to be considerably high. So, to remove the uncertainty by generating the series of discount rate and test this series with other uncertainties' to analyse the value of weir structures and to see which discount rate is appropriate under climate change conditions.

TW = Target water withdrawals (4 different water withdrawal condition is determined on the basis of development in irrigation system)

CS = climatic scenarios (generated for 2100 years for RCP 4.5 and 8.5)

4.4 Data collection:

This research is based on secondary data collected from metrological department, DCO office of the study area, PC1 of six dispersal structures on Nari River, and Irrigation department of Baluchistan.

CHAPTER 5: RESULTS & DISCUSSION

Part A: Existing analyses of the Six Flood Dispersal structure Project without climate change:

5.1 Background on the Nari River Structures Planning Problem

Pre-existing economic and financial analyses of the weir structures: The pre-feasibility assessment of project includes financial analyses and such projects were also evaluated in economic terms. Let us now consider the differences across this study and project assessment. (Table 5.1).

Table 5.1: Key economic and financial parameters and finding from projects assessment

Description	**Three dispersal structures on Nari River**	**Three dispersal structures on Nari River**
Type of analysis	Financial and Economic	Financial and Economic
Discount/Interest Rate(%)	10%	15%
Benefits (in Million Rs.)		
Existing O&M costs saved	0.737	0.737
New output agriculture	42.471	22.027
Costs (in Million Rs.)		
Scheme and land Development	2145.328*	1392.86
Operation & Maintenance Cost	10.726	5.864
Existing Output Agriculture	42.471	22.027
Results		
IRR (%)	Financial = 15.84% Economic = 17.33%	Financial = 14.87% Economic = 16.61%
Net present value (in Millions Rs.)	2490	616

***Scheme and Land Development = sum of the first 3 years cost (429.064 + 858.28 + 858.28) & the other two cost value is same and variate for next 32 years

Source: Irrigation Department Baluchistan (2015)

It is important to understand the types of cost and benefit that were included in project assessment and then we make comparison of these with our assessment under climate change.

We will see how NPV will variate under different climate scenarios and by adding certain costs and benefits that were not included in pre-assessment. For the Nari River project the cost is of two types: fixed cost (scheme and land development) and variable cost (operation and Maintenance cost annually & existing output agriculture). The economic benefit of project was received from agriculture production. O&M costs an agriculture benefits are assumed to be same in all 32 years of assessment. Agriculture benefit is calculated by using a crop production model for each crops that were cultivated there. No other cost and benefit were considered. The sensitivity analyses explored different installed capacity, the effect of Nari River flood diversion structures, and the cases with increased development cost (by 20%), decreased in developed cost (by 20%) & benefit reduced (by 20%), incremental benefit reduced (by 20%) and benefit delayed three years. No sensitivity analyses have been done by selecting different discount rate. Variations only made in IRR on cash flows under above mention criteria's (see table 5.2).

Table 5.2: Sensitivity analyses

Sensitivity analyses		**Benefits delayed 3 years**	**Incremental Benefit Reduced by 20%**	**Development cost increased by 20%**	**Benefit reduced 20% and development cost increased 20%**
S_1	FIRR	12.28%	13.70	14.30	14.08%
	EIRR	13.55%	15.07%	15.80%	15.44%
S_2	FIRR	11.58%	12.82%	13.36%	13.04%
	EIRR	13.24%	14.56%	15.11%	14.80%

Source: Irrigation Department Baluchistan

Same cost and benefits were included in financial and economic analyses.

A crucial difference between the benefit calculations in the project and this research assessment is, it has to do with the way in which agriculture production benefits were analyzed through the different level of utilization of non-perennial flow. There were also more specific differences in this study assumptions. For example, the project analysis for the S_1 structures (Mithri, Haji Sheher, & Erri) used a 10% discount rate, while the 15% rate used for the S_2 structure (Tuk, Ghazi & Khokar) project assessment. The time horizon considered for project assessment was smaller (32 years). However, in this study the assessment was longer because it takes into account the climatic uncertainties in future period (2100 years). Finally, O&M cost of both assessments were same. The calculations of the project assessment suggest that S_1 and S_2 structures are economically and financially feasible. On the economic side, they found an NPV of ~2490 Million PKR (EIRR of 17.33%) for S_1 and an NPV of ~616 million PKR for S_2 (EIRR of 16.61%).

There are some issues prevails that make the financial and economic results difficult to interpret. These issues are that: 1) it is unclear how capital costs were spread over the construction period for S_1 and S_2, 2) average optimized agriculture production was used, rather than a realistic time series of variable outputs, and 3) many economic costs and benefits of the projects were not included (rehabilitation for affected households, construction emissions, flood control, effects on downstream water demands etc.). In the next section, we turn to some of these other economic costs and benefits. Then we explain how parameter ranges were constructed for the economic analyses in this research.

5.2 Economic Costs and Benefits of the water resource Projects:

A basin-wide perspective is necessary for their economic analysis because large new infrastructure projects have effects that propagate throughout water resources systems (Jeuland, 2010). All project outputs and downstream impacts must be defined, quantified and monetized as best as possible. Table below presents a general typology of the impacts that should be considered in the appraisal of large water projects (though not all of the listed costs and benefits will apply for every project). Those included in this research have been highlighted in bold (table 5.3). This choice of impacts, previously discussed by Whittington, Hanemann, Sadoff, and Jeuland (2008) and Jeuland (2010) in Nile Basin perspective. No such study has been conducted in Pakistan that provide any guideline regarding the selection of parameters and their impacts on assessment. The assumed parameter values and possible ranges for the costs and benefits are summarized in Table 5.4

Table 5.3: Benefits and Costs of Large Water Projects, adapted from Whittington et al. (2008) and Jeuland (2010)

Benefits	Costs
Irrigation water demand at weir structure site	**Capital Investment**
Municipal and Industrial water demand	**Operation and Maintenance**
Agriculture Production	Opportunity cost of land (if not fully accounted for above)
Timely Irrigation water on downstream	**Reduced water downstream for irrigation, municipal, industrial, (including filling costs)**
Flood Control	**Resettlement for flooded households**
Decrease in impacts of drought	Compensation for lost livelihoods
Reservoirs Fisheries	**Catastrophic risk**
Recreation benefits around reservoir	Lost river fisheries & Recreation
Carbon offsets	Navigation Public health costs (water-related disease)
Sediment control	Carbon emissions (construction, reservoir clearing)
Navigation	Ecological costs (erosion, lost plant/animal habitats, etc.)
Existing O&M Costs saved	**Existing Output Agriculture**

Costs:

The costs included in the analysis are a) capital investments; b) O&M; c) costs from reductions in water availability downstream due to storage in the new reservoirs, especially transient effects that may occur during the reservoir filling period; d) resettlement for households displaced by reservoir flooding; e) economic compensation at "replacement cost" for persons otherwise losing access to land-based resources due to the projects and f) the cost of catastrophic risks. In Pakistan, for pre-feasibility projects assessment they only include the first two categories of cost. They do provide much of the needed information on other impacts in quantitative (non-monetary) terms. No tax on per unit of carbon emission is charged. During the project they don't analyze the carbon emissions generated during the construction time period. They need to be assessed and add in costs calculations. Let us now consider these costs in additional detail.

Capital costs for the six weir structures were distributed according to construction schedule presented in pre-feasibility project assessment. The total project lifespan was given to be 32 years (range 20 to 100). In Pre-feasibility study they take the total O&M cost of about 497.7 Million PKR. Annual operation and maintenance costs were assumed to be 50% of annualized capital costs (range 35 to 65%) (Jeuland, 2009). For example, for S_1 & S_2, a 50% rate implies annual O&M of about 4920 million PKR. This is higher than the ~497.7 Million PKR used in the base studies.

Table 5.4: Parameter Assumptions for costs and benefits (uncertainty ranges in brackets)

Parameters	For S1 & S2 (Combine Assessment of Mithri, Haji Sheher, Tuk, Khokar, Erri & Ghazi
<u>General Parameters:</u>	
Discount rate (%)	4 [2-8]
Weir structure project duration (years)	32 [20 – 75]
<u>Cost Parameters:</u>	
Capital Cost of Weir structures (Million PKR)	4912.386 [4666.7667 - 5649.2439]

#Household Displaced **Agriculture Production lost (Acre feet)** **Production lost (Monetary terms)** **For S_1 Area (annually) 42.471** **For S_2 Area (annually) 22.02** **Project emission (millions of tons of CO_2) *** **O&M Expenditures (as %age of capital cost)** **Cost of flood protection** **Economic loss of displaced household [Million PKR]** **Annual Variable Cost (Million Rupees)** **Fixed Cost (million Rupees)** **Annual Variable Cost Percentage**	0 [0 - 100] 232596.33 2063.712 0 2456 [1842 – 4175.2] 71.939 [57.5512 - 128.739] 0 [1.5 – 3.0] 81.08 [72.972- 89.188] 3562.18 [2849.744 - 5699.2] 0.08 [0.02]
Benefits Parameters: **Agriculture production increased at Kachhi District** **Water surplus/deficit at Kachhi District** **Decrease in Probability of Flood (%)** **Benefits of Flood Protection** **Annual Revenue Growth Rate**	Time series obtained from flow equation and production function 2.74366 [2.469 - 3.018] Vary under each climatic scenarios
Change Parameters: (%/year) **Agriculture production**	
Change Parameters: Climate (%/year) **Agriculture production under different climatic scenarios and water withdrawals conditions**	

*not calculated by project consultants.

The changes in the agriculture production is determined on the basis of changing in river flow under different climatic scenarios and water withdrawals conditions. This is one of the climate economic linkage discussed in chapter 1. The number of displaced household, according to consultants of the project is zero because the community living there had their land holding. No compensation would be given to people for their loss. The effect of the project on Kachhi district, agricultural lands and grazing would be somewhat greater. A number of farmers and herders rely on the annual Nari River flood for recessional irrigation and pasture land as seasonal water levels drop. Finally, the project study didn't include estimates of natural carbon releases and construction emissions for the weir structure project, which represent another climate economic linkage. But unable to include that in cost estimations and explain this linkage.

Benefits:

The benefits for the proposed Nari River weir structure project are; a) Agriculture production increased at Kachhi District b) Water surplus/deficit at Kachhi District c) delivery of timely irrigation water due to flow regulation; d) flood control; e) delivery of water for drought mitigation during the lean season or dry sequences of years and f) saved O&M costs. The pre-feasibility study only include the benefits generated from agriculture in 32 years and include the saved O&M costs out of these mentioned benefits. Now we will consider these benefits in additional details.

The primary economic benefit of each of the weir structure is agriculture production. The economic benefit of timely water delivery at each area agriculture - due to this project were valued at ~1660.941 Million PKR. But the benefit of agriculture will change under different climate conditions. Utilization of water is one of the main factor that bring such changes at higher level. Flood control benefits are easy to analyze on the basis of previous situation. It is easy to determine the annual cost community is bearing when their constructed gunda's breaks because of heavy flow in monsoon period. The available estimate of economic cost of flood at Nari River is ~3.067 Million PKR annually. The change in flood risks due to changes in Nari

River hydrology have been studied even less; this was assumed to be directly proportional to the reduction in peak monthly flows calculated from the flow equation.

Omissions:

A number of impacts/parameters are listed in table 5.3 that are not included in this research. And these parameters omission need to be mentioned with certain justification. First there are plans to use irrigation water supply near the weir structures given the topography, so water used for irrigation are analyzed. As no industry is installed in kachhi district so industrial demand are considered. In addition, recreation, navigation, fisheries and public health implications of the projects are not included because the Nari River canyon is not densely populated and these effects are expected to be small (according to planning commission report). Nonetheless, there have been no thorough studies of these effects and a more complete assessment is necessary. In terms of public health effects, Nari River weir structures may encourage settlement along the shores of the reservoir, which could lead to increased incidence of diseases such as water-related diseases such as malaria and schistosomiasis but the report indicate no such incident has been incurred. No compensation would be given to any household whose health is affected. Some other costs and benefits of flow regularization in the Nari River may be substantial but data are lacking to evaluate them properly: a) changes in ecosystem services from the Nari River flood other than the recessional agriculture and grazing described above. Preliminary environmental impact assessments of the structure sites did not identify critical negative ecological or habitat loss issues associated with these locations, but these may not have been sufficient. Also, secondary and economy-wide impacts – including enhanced regional economic integration, peace and cooperation, and general development impacts – are not included. Such benefits are beyond the scope of my research. By keeping these limitations in mind, we know return to the issue of aggregating costs and benefits over time (discounting). Because there is an active debate on this issue among economists. We begin with a summary of it, which then leads to an explanation of my choice of discount rates for the analysis.

5.3 Discount Rate Debate in Historical Perspective

Historically, there is an argument on choosing an appropriate way for discounting of future benefits and costs of projects concern to public interest. The two main features of the continuing debate are: 1) the ethical norms leading social discounting 2) opportunity cost of investment on which rate of returns is considered in the market. Water resource discounting debate started in early 1960s when the Office of Management and Budget (OMB) tried to regulate 10% real rate, but this was not applied to water resource projects. The discounting debate continues, in spite of general agreement of the economists and researchers that the discount rate should be lower than the that of OMB.

5.4 Discounting in the Context of Climate Change

A new debate which is common in the existing decade is the discounting in the context of climatic variability, and this debate has captured the interest of renowned economists of the world. From those renowned economists, Nordhous is of the mind that immediate and large investments are needed to reduce the impacts of climatic variability. Nicholas Stern and Cline argue that this can be achieved by assigning a low value to the discount rates. The addition of depleting natural resources and the consumption due to damages from climatic variability is necessary according to Person and Sterner. While Gasgupta argues that this is the need of today because the capacity to tackle climatic variability tomorrow will be lower than the world expects.

5.5 Arguments on Components of Discount Rate

There some key aspects of this controversy, first of them is the determination of consumption discount rate with respect to change over time. The capital's long run real rate of return is suggested by some of the literature. This method put the lower discount in questions which is suggested by economists like Stern. Question rises that why to invest in a low return projects with higher costs. Two main problems lie in this argument: 1) there is an inequality between the discount rate and long run rate of return as equality is possible in an optimum economy as Dasgupta suggests, 2) and if an optimum economy exists, there will be perfect knowledge about future for the agents, no external effects take place, which is not the case in the context of climatic variability. Such debates can be a part of water resource based long term investments as well.

The consumption discount rate ρt based on Ramsey's reasoning can be written as:

$$\rho t = \delta + \eta(ct).R(ct) \dots\dots\dots\dots\dots\dots\dots.. Eq. 1$$

where:

δ= Pure time preference

η= Elasticity of marginal utility of consumption

R= Rate of change of consumption

t= Time

According to Heal (2008), one should focus on specifying suitable expressions for elasticity of marginal utility of consumption and pure time preference before going for consumption discount rate. But this is a complicated issue. Main problem lies in the pure time preference when it is static. Which means that future generation is discounted at this rate just because they do not exist in present. Many economists suggest and the more are being agreed that the value of this parameter should be equal to zero, as we cannot discriminate amongst the generations. Some of the them suggest that the value should be a little above than zero, as extinction can occur. The economists commonly used zero or near to zero, except few who have used two or three rate in their analysis.

Another component of above equation which is dependent on consumption, is endogenous and generally is positive is the rate of change of consumption. And the last component is the elasticity of marginal utility of consumption which Dasgupta defines as “the society’s duty to avert the inequality in the consumption whether in the existing period or for the future”. All the economists assume this parameter to be constant and suggest their rates as 1, 1.5, 2, Dasgupta argues that it should be around 2 to 3.

Now, if we take *R*(*ct*), considering the current and past economic trend i-e: increasing, which means the components of the equation are positive and the rate of discounting is greater than *t*. this meets the criteria of welfare economics in which it is argued that future generations will be wealthier than the present one’ while discounting for future generations. But there are two main complications to settle 1) if the climate change impacts are negative, the equation may become negative, thus aggregate consumption will decrease, and 2) in the climate hit regions, the consumption of goods such as services provided by the ecosystems may tend to fall. And ecosystems being a complementary good to consumption, this may put ρt to a negative value. If we extend the equation by Heal’s idea, it will become:

$$\rho i, t = \delta + \eta ii(ct). R(ci, t) + \Sigma j \neq i \, \eta ij(ct). R(cj, t) \ldots \ldots \ldots \ldots \ldots EQ.2$$

The equation can be elaborated as “the ρi,t if not taken for ecosystem services could be less or greater than δ, contingent to the signs of R(ci,t) and ηii(ct). Where, R(ci,t) is the consumption of ecosystem provided services and ηij(ct) is the elasticity of MU provided by good *i* with respect to good *j*.

Uncertainty under climatic variability is another issue to tackle under existing literature on discounting. Weitzman is of the mind that if *i* and *j* are complement goods (take an example of environmental and non-environmental goods), the true value of discounting is uncertain and the ηij(ct) will be negative. Uncertainty also is an issue when dealing with the prediction of long term economic growth when using Ramsey's framework for long term investments. If growth prediction shows fluctuation, *p* should be adjusted downwards for a risk free consumption as Dasgupta suggests. This more reflect to a hyperbolic discount rate which creates a problem of inconsistency in time.

5.6 The Use of Discount Rate in Our Research

Hence, there are numerous arguments on why the rate of return on capital existing in a current market cannot be the same as social discounting. In a real world scenario, the consumption and investment in capital are usually not equal to the investment's social rate of return. But climate change allows the discount rate to be lower as it imposes threats and externalities between the generations, and that creates a strong reason to believe that *r* should be higher than the discount rate.

The recent logical discounting debate is handful to emphasize its moral dimensions, but the thing which still unclear is the practical implication when it comes to the evaluation of a project. There are two main reasons which make equation to specify: a) there is lack of agreement on what the value of *n* should be, b) probability distribution is difficult in the context of climate change and the uncertainty factor involved in the social discount rate. In this research, we have taken a simplified approach to tackle the problems. Firstly, we have considered the above mentioned different parameters used by the economists, then combining the Stern's 1.3%/year growth forecast with these parameters to determine the discount rate. The range of discount rates are used from 2 to 5 percent in which some of the economists suggest 4 percent which is the standard according to the long run capital return. The valuation and calculations in the results will base upon similar rates. And this analysis can be considered to be applicable for a country or a region with a long run economic growth of a similar state since post industrial revolution period.

In the second part of the result chapter we have used a different approach in order to prove the significance of discounting on appraisal of a project. For that, the above equation will be set for three different probable states of economic growth, in line with Dasgupta's argument by using an expressive *n(ct)* function. These three different states of economic growth with *n(ct)* will provide us an impact of how we should make decisions when it comes to social welfare projects such as six flood dispersal structures project on Nari river. This analysis is also important to fact of different opinions coming out form the literature on discounting, even though the importance of *n(ct)* is arbitrary.

5.7 Comparing economic costs and benefits of the Nari River project obtained using the hydro-economic framework with those found in the pre-feasibility studies:

In this segment I compare my approach of assessing cost and benefit with the pre-feasibility study. The comparison and discussion that follow devote particular attention to differences in the treatment of uncertainty. Key differences are summarized in Table 5.5

Table 5.5: Comparison of analyses in the pre-feasibility studies and this research

Description	Pre-feasibility study	This analysis
Type of analysis	Financial & economic	Economic only
Cost included	Scheme and land development O&M costs	Capital Cost of Weir structures (Million PKR) #Household Displaced Agriculture Production lost (because of water deficit)

	Existing agriculture	O&M Expenditures (as %age of capital cost) Cost of flood protection (Catastrophic Risk) Economic loss of displaced household [Million PKR] Annual Variable Cost (Million Rupees) Fixed Cost (million Rupees) Annual Variable Cost Percentage
Benefit Included	New output agriculture O&M Costs saved	Agriculture production increased at Kachhi District Water surplus/deficit at Kachhi District Decrease in Probability of Flood (%) Benefits of Flood Protection Annual Revenue Growth Rate
Treatment of uncertainty	Limited sensitivity analysis	Hydro-economic simulation framework
Hydrological variability	Not included	Included
Real discount rate	10%, 15%,18%	2-8
Inflation rate (%/year)	None (Real Discount Rate)	None (Real Discount Rate)
Annual O&M Expenditure (Million PKR)	530.56	2456 (%age of capital cost)
Runoff level	Determined by using historical data for 32 years	Generate the flow equation through linear regression and make projection of the runoff for 2100 years by using the RCP's 4.5 & 8.5
Agriculture production	Crop production function (short run-analysis)	Crop production function (time series of annual agriculture production for 2100 years is generated)

5.8 Key differences between the analyses

The first important difference between the two types of studies is the fact that the prefeasibility analyses mostly focus on financial aspects, and largely ignore economic impacts. These financial analyses nonetheless have important deficiencies. It is certainly reasonable to limit the domain of financial costs and benefits to capital, O&M and Agriculture production generated by the project, since these represent the costs and revenues the projects would need to balance. Externality effects from changes in water availability, floods, and the true economic opportunity cost of land lost probably would not figure into this financial assessment. However, some other aspects – for example resettlement and rehabilitation – should be included if compensation will be paid. Perhaps more crucially, it is inappropriate to use optimized agriculture production (generated by using historical flow data) to predict financial revenues from the sale of agriculture produced. It would be preferable to simulate the performance of the system through some believable hydrological series (perhaps even observed historical flows).

Another important difference between the economic and financial analyses in the pre-feasibility study and the one conducted here has to do with their treatment of uncertainty.

The Pre-feasibility study, as mentioned in section 5.2 does sensitivity analysis of project by using higher discount rate and by increasing and decreasing cost and benefits and through delayed development. Unfortunately, there is no way of really knowing from the documents whether the Cameos consultants have indeed studied the effect of the most important uncertain parameters. This analysis addresses this shortcoming by investigating how outcomes vary over the parameter ranges specified in section 5.2. This variation is studied for each uncertain parameter individually, as well as in combination with other parameters. It also includes natural hydrological variability and generate production at future year by using future river flow projections rather than average optimal annual agriculture production, by integrating the hydrological and economic simulations. The final important difference between the two types of analyses compared in Table 5.5 has to do with the specific parameter assumptions they make. Most of these have already been discussed. The most consequential of these differences has to do with the discount rate that is used.

5.9 The treatment of uncertainty in the economic simulations of this analysis

The preceding discussion about uncertainty necessitates several clarifications regarding the use of the analytical framework of this research for understanding uncertainty in the economic performance of this project. A reader might note that the economic simulation procedure discussed in Chapter 4 requires random sampling from specified distributions of the parameters that appear in the valuation equations. In Section 5.2, the basis for these parameter ranges was discussed, but nothing was said about their distributions. I now describe my rationale for them. The parameters distribution are summarized in table 5.6. Highly uncertain parameters are defined to be uniform over their specified ranges, because there is limited evidence to inform more precise specification. Triangular distributions are used when more confidence in parameter values is possible, in which zero probability is assigned to the lower and upper bounds of the specified ranges and the frequency distributions increase linearly from the lower bound up to the most likely value and back down to the upper bound. The use of uniform (and triangular) probability distributions for parameters is not typical in Monte Carlo analysis. For one, it suggests that little is really known about the probabilities of the uncertain parameters (which is the case in most applications of the sort explored in this research). But from a frequentist's perspective, it may make little sense to use a precise tool like Monte Carlo simulation when knowledge is limited in this way.

Table 5.6. Summary of parameter distributions for economic simulations

Uniformly Distributed Parameters	**Triangular distributed parameters**

Discount rate	Capital Costs (Million Rs.)
Number of Displaced Household	Annual operation and maintenance cost (as % of annual capital cost)
	Expected annual cost of flood damage
	Weir structure project duration (project life span)
	Benefits of Flood Protection
	Agriculture Revenue
	Annual Variable Cost (Million Rupees)
	Fixed Cost (million Rupees)
	Costs of displaced household

Through simulation, it gives better understanding of which parameters have the highest effect on the NPV outcomes, and under what conditions.

5.10 Economic Analysis of Nari River Project:

I now proceed with the economic analysis of the project pre-feasibility study. For the purpose of comparison, this project are evaluated for the situation explored in report, i.e. no change in climate conditions, natural hydrological variability, or water withdrawals. The analysis is intended to demonstrate the types of results that can be obtained using my analytical approach. In particular, we focus on the effect of 1) including additional costs and benefits beyond the restricted set included in the pre-feasibility studies, 2) hydrological variability, and 3) uncertainty in the value of the economic parameters. The base case analysis uses the limited available historical time series of hydrology (1961-1971 & 1986-2003) and the base case economic parameter values shown in Table 5.1. The uncertainty analysis then explores the consequences of hydrological variability and uncertain economic aspects of the planning problem.

5.11 The Base Case Analysis for Nari River:

The results for the base case analysis are summarized in Table 5.7. The S1 and S2 structures project both have different IRR of about 10% and 15%. The S1 structures has the highest NPV, followed by S2. Both structures project assessment easily pass a cost-benefit test. The pre-feasibility study, however, claim much higher IRRs for S1 and S2 project.

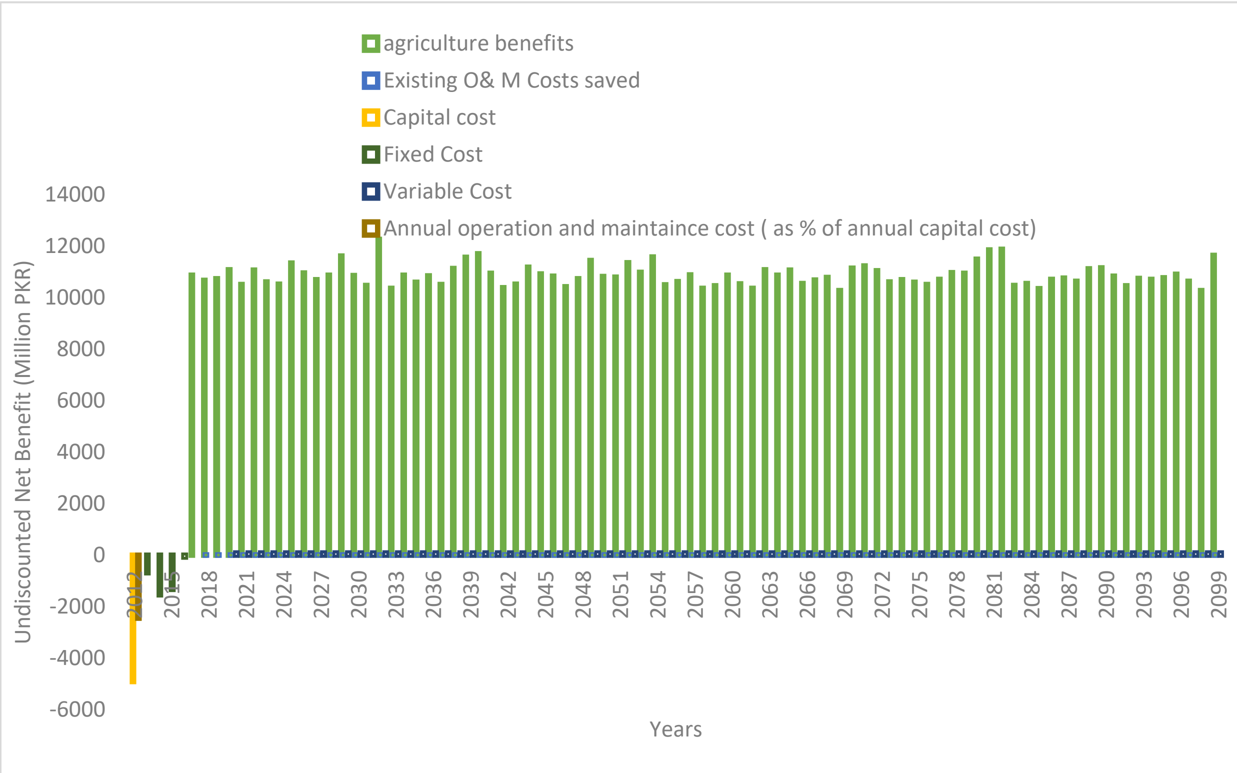
Table 5.7: Base case economic results for S_1 & S_2 weir structures

	For S_1 Structures	*For S_2 Structures*
Benefit Cost Ratio	1.62	1.08
*Net Present Value (Million PKR)**	2490	616
Internal Rate of return	10%	15%
*Economic IRR from pre-feasibility study**	17.33%	16.61
*Financial IRR from pre-feasibility study**	15.84%	14.87

*generated on 32 years of operation

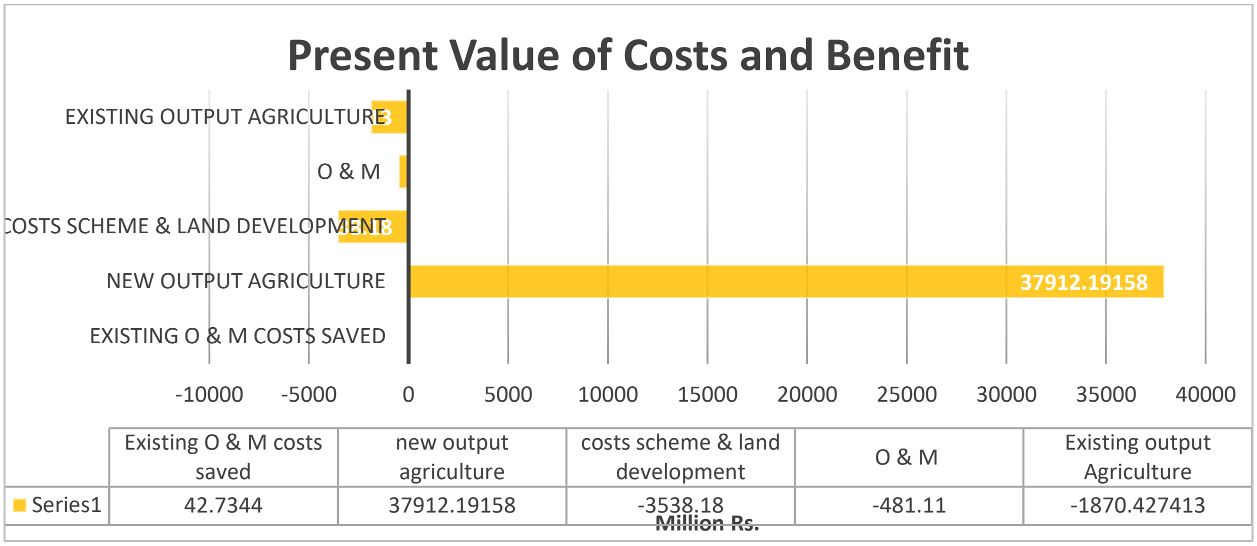
It is unclear why the pre-feasibility study conduct the assessment of 6 weir structures in segments.

Figure 9: Time series of undiscounted net benefit from Nari River in the base case analysis:



There is a lot of difference between the estimated benefit by the base case study and our analysis. The benefit generated through agriculture in the base case would be somewhat lower than our case because previously the water utilization is poorly managed. Wastage of water would be higher. According to the base case study the benefit generated through agriculture annually would be 42.471 Million PKR for S_1 and in 32 years it will increase up to 1055 Million PKR. For S_2, the benefit from agriculture annually would be 22 Million PKR and it will increase up to 606 Million PKR. When by using the same production function for two crops we generate the agriculture benefit for 2100 years our result would be very much different. The value of agriculture revenue would lies between 10000 to 12000 Million PKR annually. The benefits would only be achieved if the water utilization would be efficient in agriculture sector. The variation in each year agriculture benefits occurred because of reduced flows in some years. The base case benefits estimation is based on historical flow data which can be criticized on the ground that previously no structures are available because of which community is unable to store the water they only utilize the water in monsoon period according to their needs and the excess water get wasted. For the correct assessments of agriculture benefit there is need to use the generalized future flow of water because now the water storage facility is available and communities now able to use it in dry month. The few important things that needed to understand is; firstly the “average” agriculture production that is assumed in the pre-feasibility study is based on optimal agriculture production (in historical period). However, it actually relies on perfect hydrological foresight. For example generates annual agriculture benefits that are somewhat less on average than the assumed 550 million PKR. My analysis may over estimate agriculture production, since reasonable inflow forecasting systems exist and could probably be used to improve agriculture output. Secondly, the project study underestimate the project costs and benefits. The project costs doesn’t include the costs of flood protection. The types of costs and benefits of this projects in the “historical situation” are very different from those included in the pre-feasibility studies. As shown in Figure 8 for the Weir structures project, the costs are primarily for land & Scheme development, existing agriculture, and operation and maintenance. The benefits are mostly agriculture production increase plus a small amount of O&M costs Saved. These calculations do not necessarily imply that the same categories of costs and benefits will dominate the analysis in other plausible future situations. This historical case does not include cost and benefits that are received through flood protection. We will revisit these aspects in Part C of this dissertation, where different future conditions are considered.

Figure 10: Present Value of Costs and Benefits for Nari River in the Base Case Analysis:

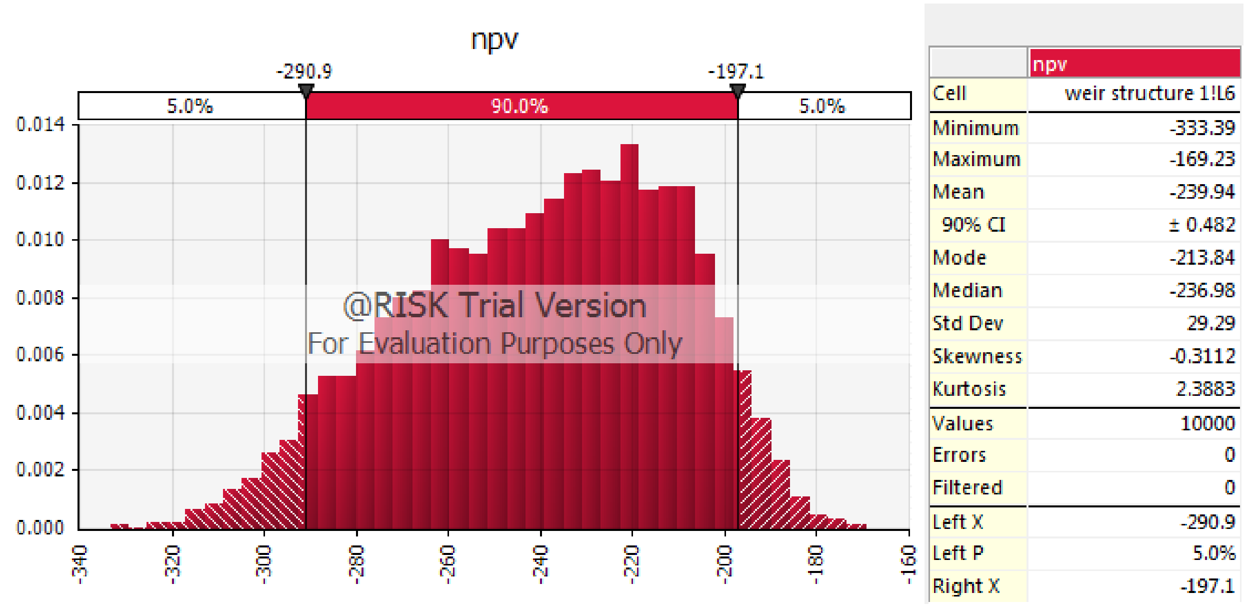


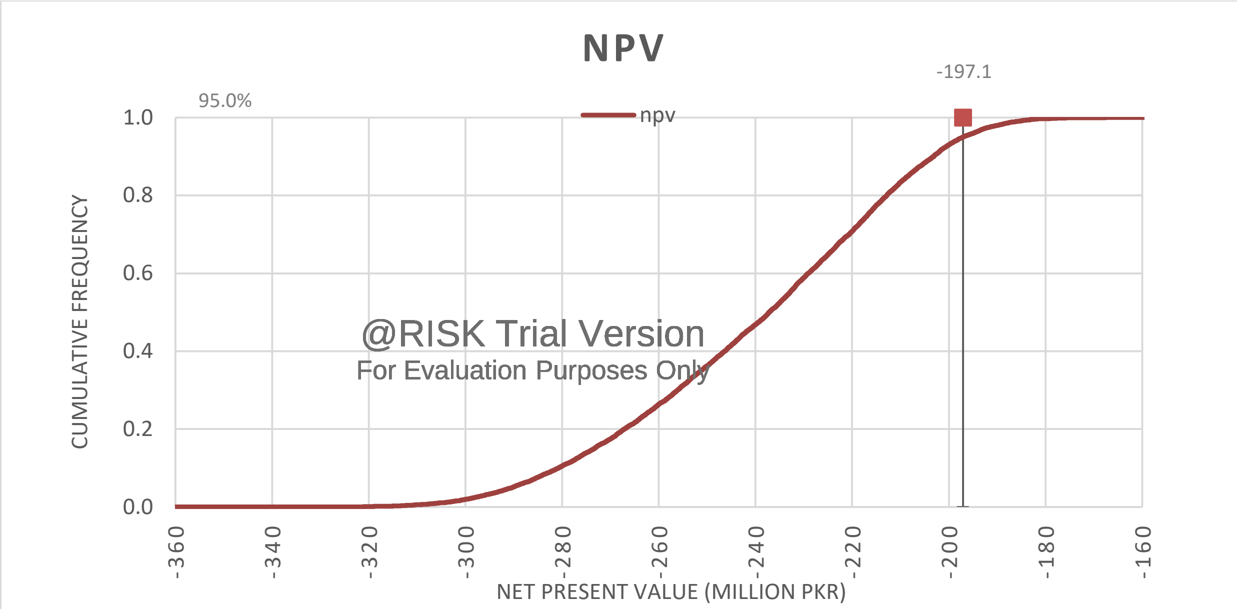
5.12 Analysis with hydrological and economic uncertainty

We now turn to the analysis of sensitivity of these results to uncertainty in the cost-benefit model parameters. Using the simulation procedure described previously, a cumulative distribution of NPV outcomes can be generated for weir structures based on the outcomes from each Monte Carlo trial (Figure 10 A&B). Unlike that simple calculation, however, we see that the NPV outcomes vary considerably given the ranges and distributions of parameters discussed previously in this chapter. There are many realizations for which the NPV of this project is negative, exceeding -150 Million PKR (10% for S_1); these tend to be simulated outcomes where the Costs of the project is higher than their benefit (Figure 11). There are also many plausible outcomes with NPV below -260 Million PKR (15% for S_2); these are outcomes where discount rate would be higher, capital costs of the project is higher and the agriculture benefit would be lower (Figure 11). In only about 90% of simulations is the NPV for any of these projects negative. A large difference in NPV values would arise by using the same higher discount rate used by project consultants. This difference occur because of adding other uncertain economic parameters that are needed to added for assessment (such as cost and benefit of flood protection, cost of household displacement, capital costs, and O&M Costs (as %age of capital cost)). However, the agriculture benefit used in these estimation would be generated by using the production. These benefits are higher than those specified by project because they are analyzed through full utilization of water.

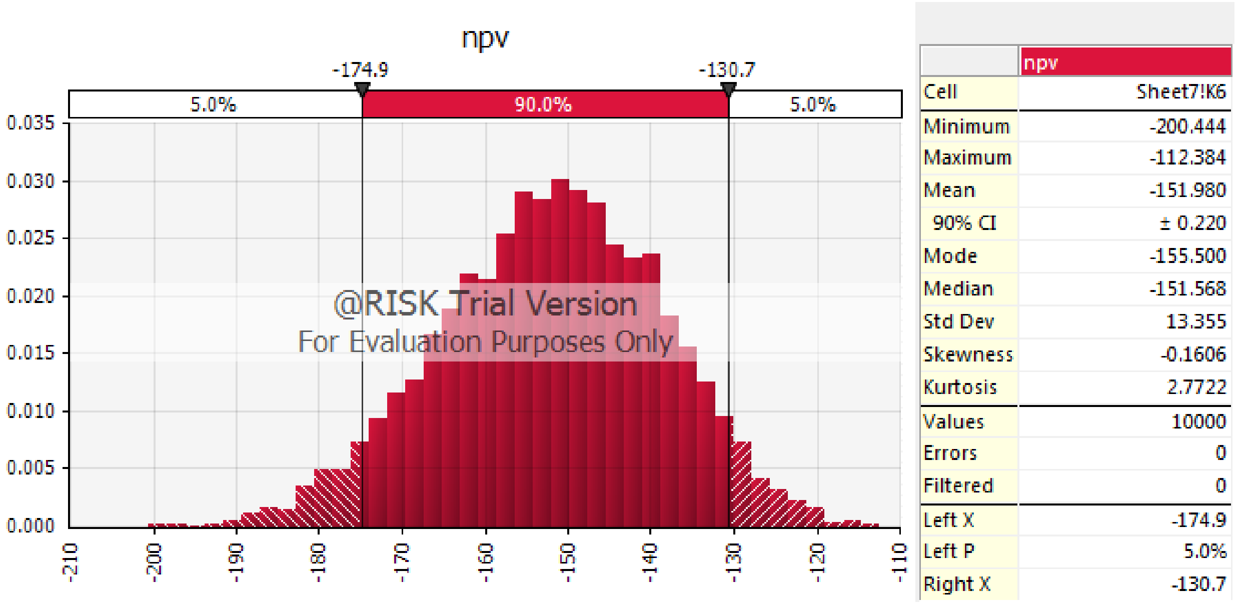
Figure 11: A) Cumulative Distribution of NPV for S1 Structures B) Cumulative Distribution of NPV for S2 Structures

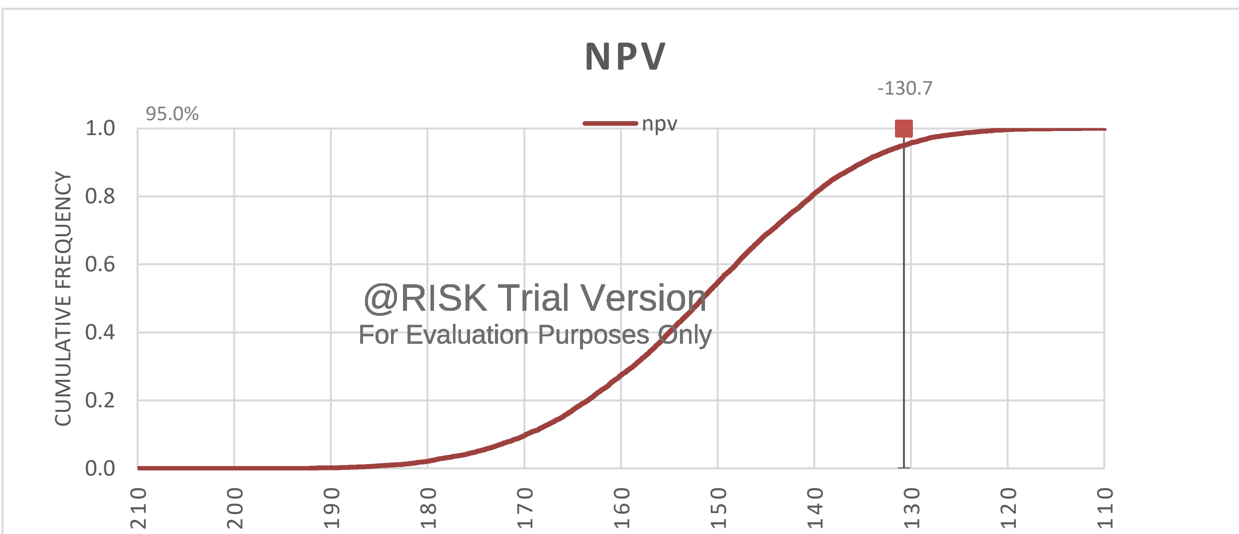
A) ***Cumulative Distribution of NPV for the S_1 structures***





In first figure, it is shown that the probability that the NPV would lies between the ranges of -290 to -197 Million PKR would be 90%. The grid box shows the least possible expected value and the highest expected value of NPV. The probability of negative NPV outcomes will be 95% which is obtained by putting the value zero on the left slider of second figure. This shows that there is 5% probability that highest NPV that would be achieved, will be -160 Million PKR for the S_1 structures **B) Cumulative Distribution of NPV for the S_2 structures:**



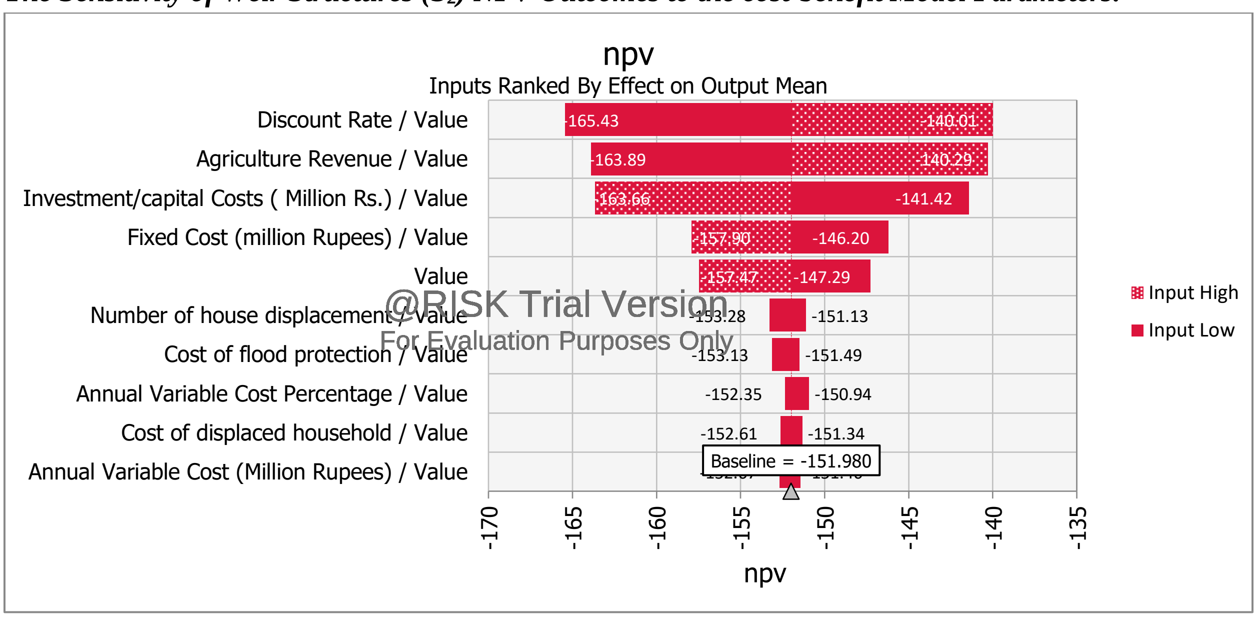


The cumulative distribution of S_2 structures shows the higher NPV (but negative) as compare to the S_1 structures. The figure B (1) shows the probability that the NPV would lies between the ranges of -174 to -130 Million PKR would be 90%. The grid box shows the least possible expected value of -200 Million PKR and the highest expected value of NPV -112 Million PKR. To know the probability of negative NPV outcomes. We put the value zero on the left slider of second figure. This shows that the probability that NPV would be smaller than -130 Million PKR for the S_2 structures would be 95%.

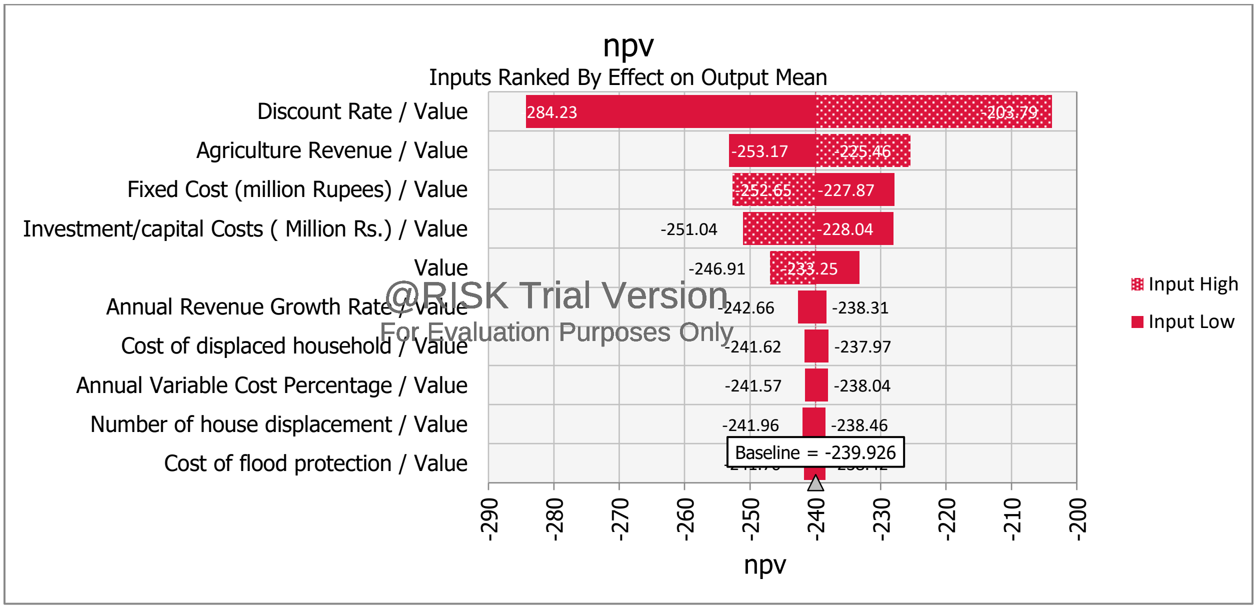
It is informative to explore which parameters contribute most to suppress the NPV outcomes shown above. Figure 11 only presents these detailed results for the 10 most influential parameters in altering weir structures NPV. The parameter which has the greatest effect on outcomes is the discount rate, because project costs fall mainly at the beginning of the lifespan and benefits extend far into the future. In S_1 structures NPV would be negative because the capital costs and O&M costs would be the 3rd and 4rth highest contributing factor in NPV. Discount rate is the highest contributing factor that had larger effects on the NPV. Higher the discount rate used in project lower would be the NPV. The statement get fulfilled. For the S_2 structure 15% discount rate is used so its NPV as compare to S_1 NPV is higher (but negative).

Figure 12: Balance of Costs and Benefit Components for the highest and lowest of 1% of NPV outcomes, historical Conditions

The Sensitivity of Weir Structures (S_2) NPV Outcomes to the cost-benefit Model Parameters:



The Sensitivity of Weir Structures (S_1) NPV Outcomes to the cost-benefit Model Parameters:



Somewhat more important factors are the natural variability in the river (as indicated by the randomly selected sequence of historical inflows for generation of agriculture benefit (#2 in S_1 & S_2), and the development cost uncertainty (#2 for S_1 &S_2). The least important factors are the costs that are incurred for flood protection. The cost is low that's why its effect is smaller on NPV. The same factors appear in the tornado diagrams for both structures segments, mostly in the same order. The influence of hydrological variability, however, decreases as one moves downstream among the sites, from Mithri to Erri to Khokar. The land development costs is higher at downstream weir structures. The other important difference is the appearance of the parameter for the value of agriculture production for the S_1 structures, which has the largest land area and therefore provides the larger benefits then at the downstream. The similarity of these results across weir structures should reassure readers that even if the parameter distributions and ranges are not precisely correct, the ranking of these 2 structures segments under these conditions should remain approximately the same.

Let us now consider in additional detail the influence of hydrological variability on NPV outcomes for Nari River Project. In Figure 12, we see the effect of "fixing" the hydrology at best, worst, average and historical conditions. Each of these is selected as follows. The “best synthetic hydrology” is identified from the tornado diagram analysis to be the synthetic series (from the set of 2100 years series’ generated for this system as described in Chapter 4) for which the NPV of the project, based on incremental changes in system outputs, is highest. The “worst synthetic hydrology” is the opposite case, yielding the lowest NPV. The “average synthetic hydrology” is obtained by averaging the incremental changes induced by the project across all 2100 synthetic series’. Finally, the “historical hydrology” is the result obtained using the available historical flow record for the system. We can see that the spread in the cumulative NPV distributions is relatively modest across these sequences, and that the historical series lies close to the “best” series. This should not be surprising given the fact that the rule curves for these dam’s/weir structures were devised by optimizing agriculture production using the historical series. The synthetic flows generated for the analysis thus appear to yield reasonable results.

Summary:

This chapter reviewed previous economic and financial analyses of the six flood dispersal structures– Mithri, Erri, Haji Sheher, Khokar, Tuk and Ghazi – considered in this research. The economic costs and benefits that should be included in a more complete assessment of these structures were then discussed. The current debate on discounting in the context of climate change was also related to the economic analysis of large public investment projects. Next, a comparative economic analysis of the S_1 and S_2 Structures under existing conditions was conducted. The analysis showed that the project IRRs were the same quoted in the project pre-feasibility studies, but that they nevertheless all had negative NPV under virtually all plausible combinations of uncertain economic and hydrological parameters. The effect of the economic parameters was shown to be much more important in determining these outcomes than the natural hydrological variability in the system. Whether these results continue to hold under different climate scenarios, water withdrawal conditions and states of the world will be the focus of Part C of this dissertation.

Part B: INTEGRATING PLANNING UNCERTAINITY INTO ANALYSIS

In this section we discussed the two dimension of unmeasurable uncertainties (Climate projections and water withdrawals) effect on the Nari River system. We begin this chapter by first explaining the set of climate scenarios and water withdrawals conditions based on projections that represents a range of situation that seems plausible over the 2100 year planning horizon for the weir structure project.

Mentioning the conceptual diagram of these evolving uncertainties first described in chapter 1 and considered in this research (Figure 12). We derived the runoff of Nari River under various climatic scenarios and make a comparison between these withdrawals and available runoff (based on projections). It is therefore worthful to use this chapter to describe the baseline that is uncertain, dynamic and comprised of the two dimension of climate change and evolving water withdrawals.

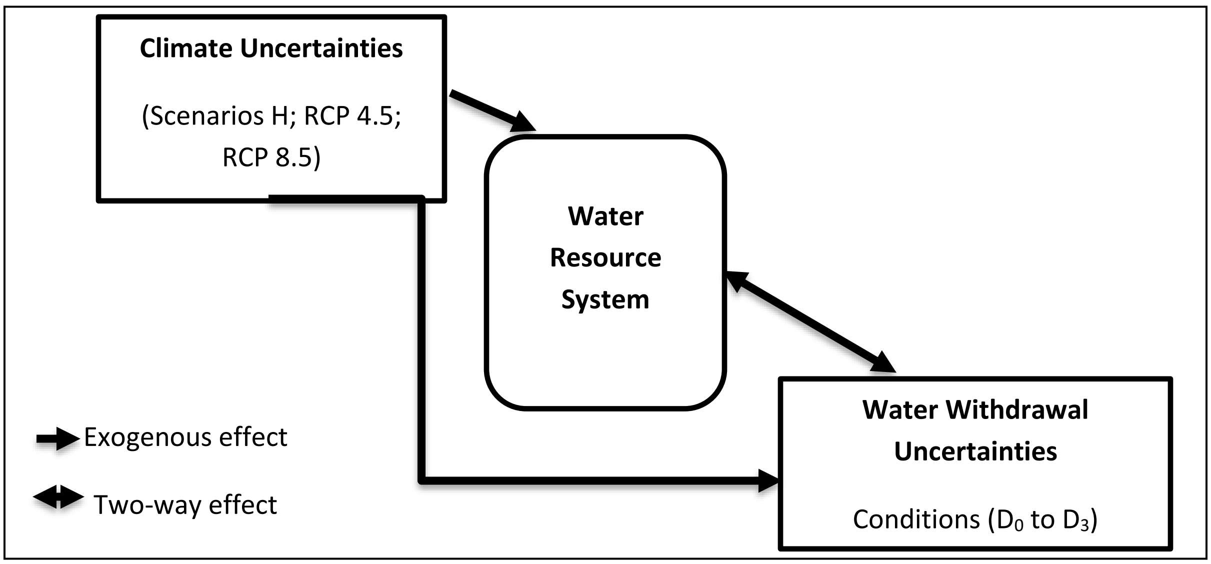


Figure 13: the focus of the analysis in this chapter: the two dimensions-climate change and evolving regime of water withdrawals-of unmeasurable uncertainties in the value of weir structure project (with Scenarios and Condition names).

The purpose of this chapter is to explain three things 1) the difference between the current conditions and condition with changes (increase on decrease) 2) the incremental effect of adding climate change to these withdrawals condition 3) the total effect of increased withdrawals + change in climate over and above the current situation in the basin. This is the first time that these aspects have been considered in the Nari River context or in a river assessment.

5.13 Water Withdrawal Conditions:

The three withdrawal conditions are explained in table below. The first condition is the status quo condition (hereafter called D0). This condition includes the current irrigation schemes (the diversion structures) and withdrawals from the system. Total withdrawals at Mithri weir is 15.69 bcm/year (15690 mcm/year). The flow is dependent on climate condition if climate condition is not in favored the river flow reduced and unable to meet the target demand. We analyzed the historical flow and flow under different climatic scenarios. And how these changes in flow affect the withdrawal condition are analyzed. Two conditions with increasing withdrawals are considered. And make a comparison of such increase with the projected flow.

- Low Development (D0): utilize 25% more available discharge than status quo condition for irrigation
- Moderate Development (D1): utilize half of the available discharge for irrigation/half of the additional potential irrigation project.
- High Development (D2): which include all additional withdrawals.

We will see that D1 and D2 development conditions lead to shortfall under some climatic scenarios. For this reason a fourth adaptive development condition (D3) is developed. We are doing this to investigate what would happen to system if withdrawals are reduced to the lower basin to respond to insufficient flows.[7]

[7] In my analysis the D0 condition contains the current flow at Nari River because of dispersal structure project. The other 3 conditions are only different from D0 by their water withdrawals. It thus become easier to determine the physical changes in the system. These changes are associated purely with changing withdrawals.

Table 5.8: Summary of water withdrawals conditions:

Development Condition	Description
Status Quo (D0)	Current Irrigation Scheme and existing irrigation withdrawal from the system
Low Development (D1)	D0 demand + increase in water withdrawals by 25%
Moderate Development (D2)	D0 demand + increase in water withdrawals by 50%
High Development (D3)	D0 demand + increase in water withdrawals by 100%.
Adaptive Development (D4)	D2 demand reduced by 20% because of lower availability of water.

The first important thing to consider, when assessing these water withdrawal conditions. Nari River water rights are settled a century ago in British era. According to which the perennial flow of the river (120 cusecs to be specific) is the right of the people of district Sibi. The excess flood water was transferred towards district Kachhi and was utilized by the people of Kachhi by putting gunda's. The three water withdrawals condition might be judged consistent with the planning commission Report, since the withdrawals are 15.69bcm (this value is the sum of flow from year 1986-2001. Out of which only 3.69bcm is utilized.12bcm get wasted. 15.69bcm is the surface water flow (flood and runoff) it doesn't include the ground water level (which is 1.07bcm in these years) and Indus perennial flow (which is 4.76bcm in these years). Secondly, the important complication relates to the increasing kachhi district water withdrawals that are included in D1, D2 and D3 water withdrawals conditions. The project will increase people ability to irrigate more area of land and grow those crops that are not related to their pattern of production. This reflect the increase in withdrawals at kachhi district. Also, in cases where system water availability becomes insufficient[8], community living near Nari River would probably reduce withdrawals to avoid damaging water deficits and improve reliability. This serves as motivation for the D4 condition, which explores the effect of a 20% reduction in withdrawals because of lower water availability.

Finally, the third important thing is to relate the effect of climate change on the demand for water in irrigation. When climate linkages are included using the production function approach described in Chapter 4. We will generalize the benefits of agriculture on the basis of the available flow under different climatic condition. In this chapter, two types of calculations and results for the system behaviour in this dynamic baseline are presented. The individual and combined effects of the various physical climate linkages on the water balance at Nari River are assessed and described. I then perform a few illustrative calculations that allow increased withdrawals & decreased withdrawals under climate change. I include these calculations simply to demonstrate to water resources planners that the consequences of climate change extend well beyond the effect of perturbed river flows.

5.14 Climate Scenarios:

We next consider the three climate scenarios. The three types we constructed is: 1) The historical climate scenario; 2) two IPCC-type RCP's 4.5[9] & 8.5 climate scenarios; and 3) climate

---

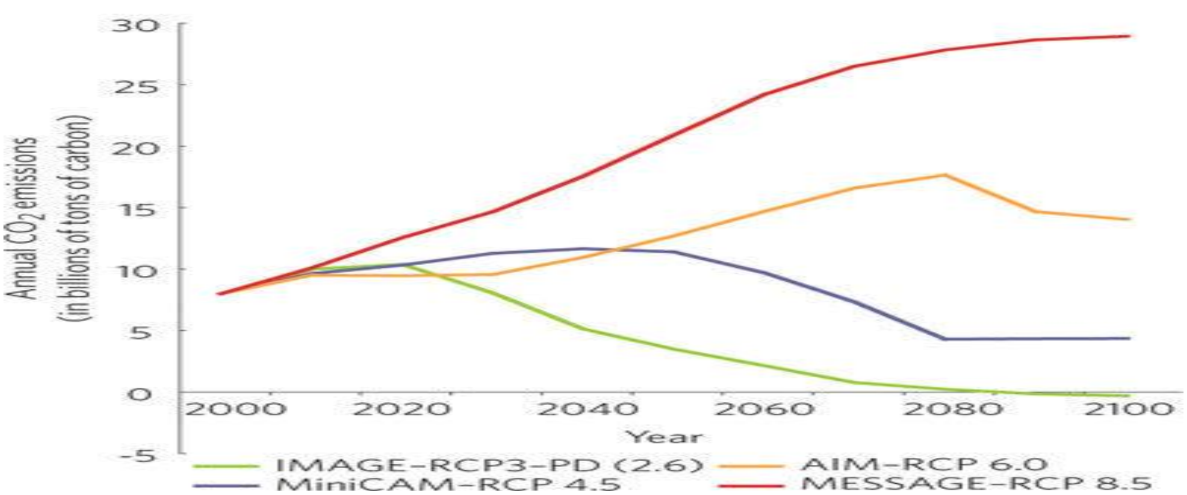
[8] As shown in next section under different climatic conditions the flow of river is expected to reduce as compare to historical conditions.

[9] The RCP 4.5 is developed by the MiniCAM modeling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI). It is a stabilization scenario where total radiative forcing is stabilized before 2100 by employment of a range of technologies and strategies for reducing greenhouse gas emissions. The scenario drivers and technology options are detailed in Clarke et al. (2007). Additional detail on the simulation of land use and terrestrial carbon emissions is given by Wise et al (2009).

The MiniCAM-team responsible for developing the RCP 4.5 are:

sensitivity scenarios (Table 5.9). the mean precipitation is maintained in historical scenario. Based on the historical series, inflow's statistical properties are specified. The RCP 4.5 and 8.5 which are the IPCC's scenarios, use rainfall projections on catchment level and the projected run off series is generated through a flow equation which follows logistic distribution. Under both scenarios, projected runoff series are generated. If no action is taken to fight climate change, the RCP 4.5 and 8.5 will reflect future emissions in line with the IPCC's predicted ones. The figure 14 shows the annual CO2 emissions (in billions of tons of carbon) out to year 2100 for each of the RCP. The RCP's range is wider than that information provided in previous reports of IPCC, which is reflecting a partial shift to a scenario where future emissions look more extreme than they were a decade ago. An optimistic scenario is also included in RCP, which is 2.6 Wm-2 scenario, dropping GHGs emissions to zero by 2070 and after then continuing to decrease, making world's emissions negative (actually pulling GHGs out of the air and locking them away for decades.

Figure 14: Annual carbon dioxide emissions (in billions of tons of carbon) out to 2100 for each of the RCPs



Allison Thomson, Katherine Calvin, Steve Smith, Page Kyle, April Volke, Pralit Patel, Sabrina Delgado, Ben Bond-Lamberty, Marshall Wise, Leon Clarke and Jae Edmonds

Source: Data from RCP database (http://go.nature.com/Rmyxyt).

The 8.5 W m−2 case which is high end, CO2 levels surpass an enormous 1300 PPM by the end of the century. Jeuland (2010) argues that the relevance to investment planning may be interrogated in light of future possible mitigation attempts. Some climate sensitivity scenarios are also used in the research, however, those are arguably less natural. Those are constructed to check the sensitivity of the system to variabilities in the inflow's statistical properties. The initial set of scenarios is used to understand how outcomes of a system are affected by changes in rainfall and runoff. Such scenario is referred as IΔX scenario, where I is the "inflow" and ΔX indicates the percentage change in runoff, e.g: I-5 means a 5 percent fall in the estimated runoff of each year.

Table 5.9: Summary of climatic scenarios

Climatic Scenarios	***Description***
Historical Climate (H)	Analyses based on the annual historical (actual data) inflows.[10]
IPCC-type RCP's 4.5&8.5 scenarios	Analyses based on the annual historical inflows perturbed by the percentage changes in annual runoff obtained from using the flow equation that based on the projection of precipitation at catchment area.[11]
Inflow sensitivity analyses ΔX % Mean Inflows (IΔX) [ΔX=-20,-10,+0,+10,+20]	Analyses based on annual historical and future projected inflows perturbed by the same percentage changes ΔX.[12]

[10] For analyses with actual historical flows, past 30 years data of precipitation and runoff is used

[11] A projected series of future inflow are generated under the climatic scenarios of 4.5 and 8.5 scenarios are taken from the fifth assessment report of IPCC. The projection of future monthly precipitation of catchment area is taken from PMD, website. By converting monthly precipitation into annually, we generated a flow sequence for 2100 years.

[12] For sensitivity analyses, the projected flow annual data under different climatic scenarios will reduced/increased by 10% & 20% and analyses its impacts on the system and value of weir structures

The I∆X scenarios reflect the high degree of uncertainty in climate change projections for Nari River catchment area rainfall. The bounds on changes in runoff in these scenarios were selected based on rate of changes in each year flow found in the literature/ historical data. (See appendix). Two scenarios for increases in runoff were also included (+10% and +20%). These are motivated by work that suggests that water availability may increase in some parts of Baluchistan (as mentioned in literature) but catchment area precipitation doesn't support that argument.

Generation of Flow equation:

For generation of projected runoff under RCP 4.5 and 8.5 we need a flow equation that shows a relationship between precipitation and runoff. Because the data of projection shows a monthly precipitation (in mm) for 2100 years of Nari River catchment area. The relationship equation is determined by using the historical data. The summary statistic of this historical data is given below:

Table 5.10: Summary Statistics of Historical Data

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Flow (MCM)	31	0	31	172.0000	5802.0600	1598.2900	1233.1646

From past 30 years, the minimum flow of Nari River is 172 mcm. The maximum flow is 5802 mcm.

Steps 1: First we apply the Maximum likelihood estimation[13],

[13] Maximum likelihood estimation initiates with a mathematical expression known as the Likelihood Function of the sample data. It is for estimating parameter(s) of a model for given data. MLE gets estimates which explains the data best. Simply having a set of data, allowing the chosen probability distribution model and it contains the unknown model parameters. Sample likelihood is optimized by the value of these parameters are known as the Maximum Likelihood Estimates or MLEs. Maximum likelihood estimation is an entirely analytic maximization

We apply this test, to fit an appropriate distribution for river flow data conduct the distribution test. ML estimation gives parameter values by using most likely sample so it is used to perform this test for various distributions. Distribution fitting can be analysed by two test Chi-square and KGS. KGS is used to decide whether our given data is from logistic distribution or not, which is recommended from ML estimation. KGS is preferable to Chi square because KGS gives exact estimation and Chi square requires adequate sample size for valid results.

Table 5.11: Results of Maximum Likelihood Estimation:

Distribution	p-value
Beta4	0.0950
Chi-square	< 0.0001
Erlang	0.0016
Exponential	0.3928
Fisher-Tippett (1)	< 0.0001
Fisher-Tippett (2)	0.0847
Gamma (1)	< 0.0001
Gamma (2)	0.7749
GEV	0.0223
Gumbel	< 0.0001
Log-normal	0.7793
Logistic	**0.8240**
Normal	0.1652
Normal (Standard)	< 0.0001
Student	< 0.0001
Weibull (1)	< 0.0001
Weibull (2)	0.6497
Weibull (3)	0.6632

The distribution that fits best the data for the goodness of fit test is the Logistic distribution.

Step 2: Kolmogorov-smirnov (KSG) test is applied;

procedure. MLE applies to every form of data (censored or multicensored), and also applicable across several stress cells and estimate acceleration model parameters.

Table 5.12: Results of Kolmogorov-smirnov test

Kolmogorov-Smirnov test:

D	0.1102
p-value	0.8240
Alpha	0.05

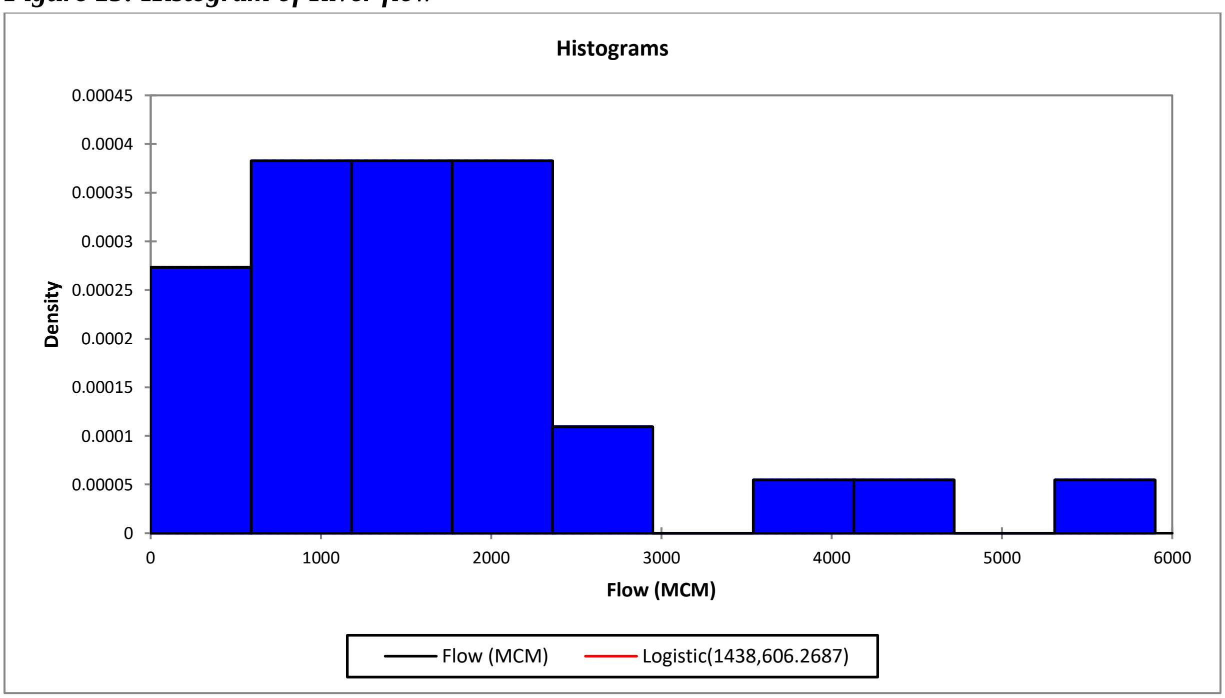
Test interpretation:
H0: The sample follows a Logistic distribution
Ha: The sample does not follow a Logistic distribution

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is 82.40%.

Conclusion: Distribution fit test supports logistic distribution. For river flow data logistic distribution is applicable due to thickness in tails. Hypothesis test also supports its application that is apparent from p value of 0.82. It refers that probability against null hypothesis is very low.

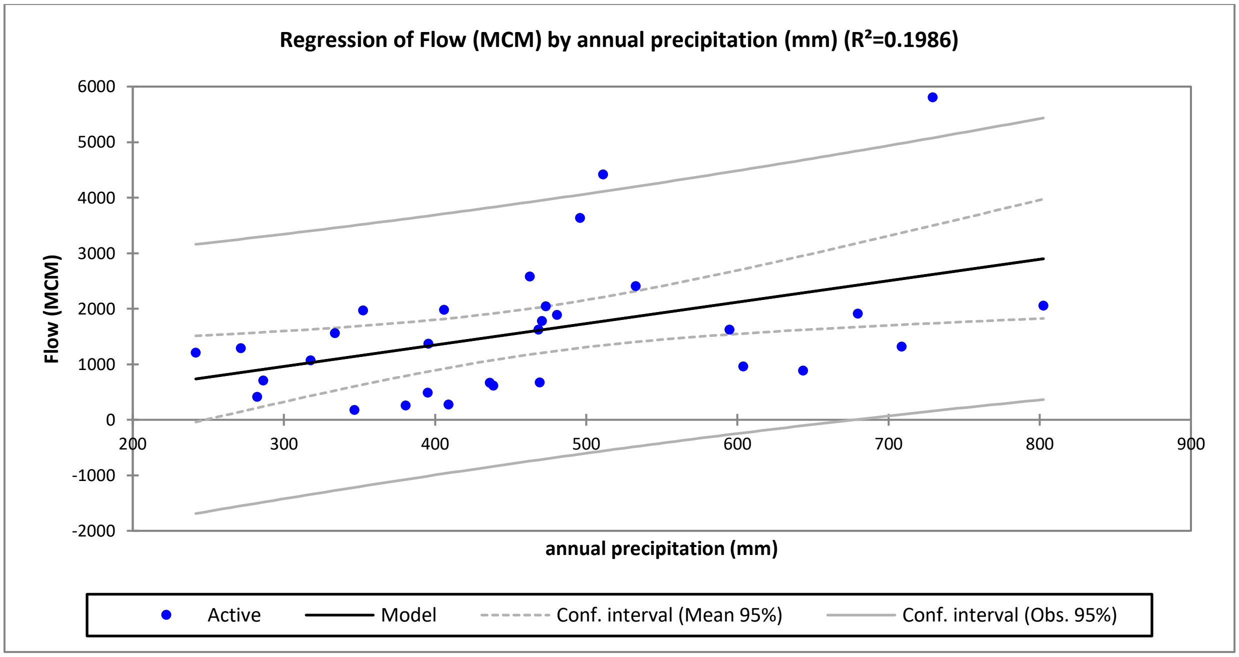
Figure 15: Histogram of River flow



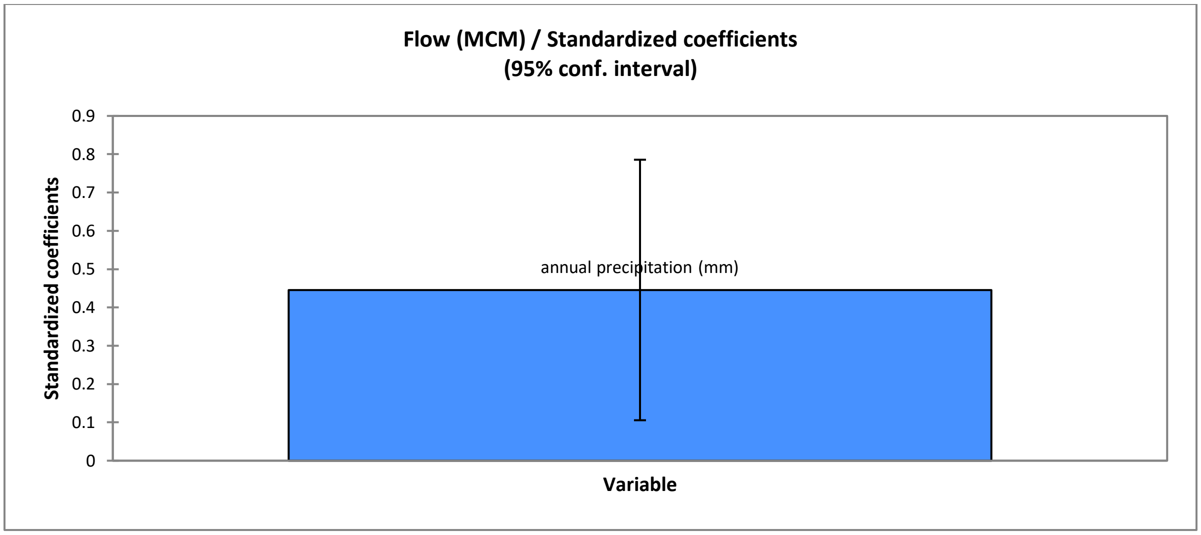
Histogram of River flow represents a flow is mostly between 500 to less than 2500 MCM. There are some periods of high and extremely high flow rate that is more than 4200 and approximately 6000 mcm.

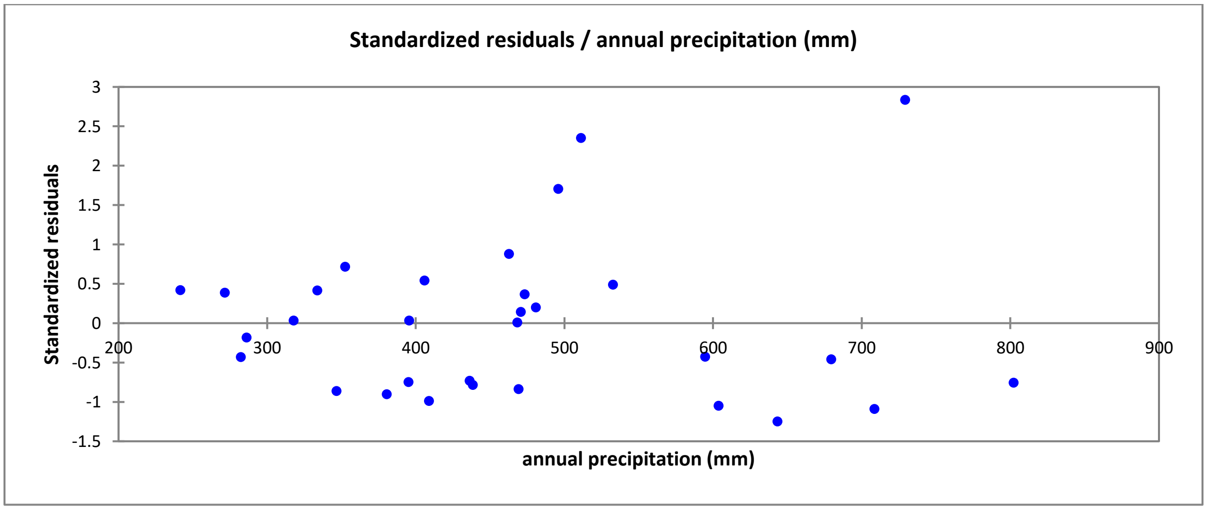
STEP 3: LINEAR REGRESSION RESULTS:

Figure 16: Linear Regression Results:

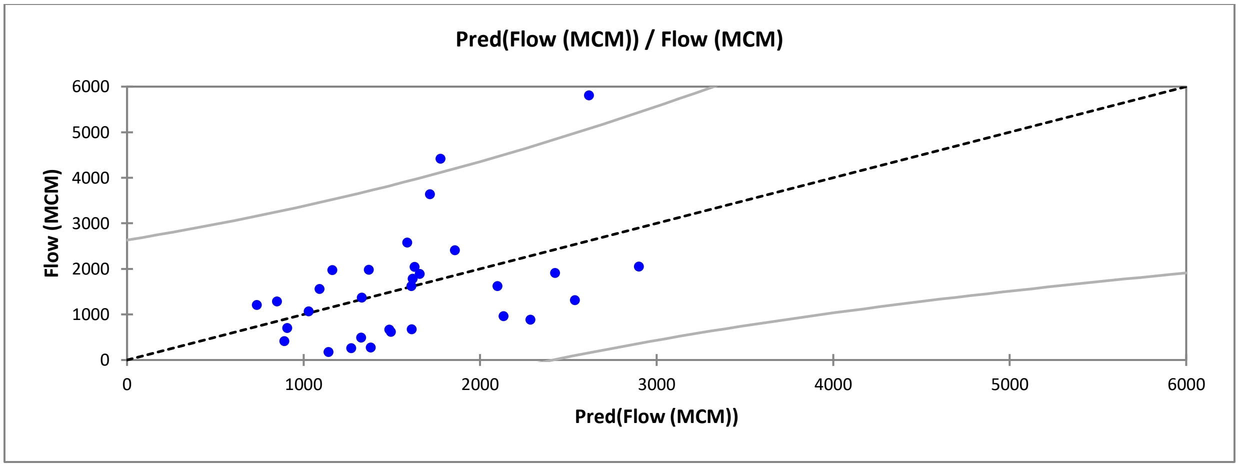


The first chart "Regression of Flow..." provides visualization of data and fitted model along with confidence intervals. One is the 95 % CI for average prediction of annual precipitation. From the fitted regression it is evident that there is some positive relationship between precipitation and river flow however the linear trend has high variability and there are few outliers representing some periods of high river flow with no significantly different precipitation rate. These are the data points outside the second CI that is for spread of data values this CI is also given at 95% range.





The second chart is for "standardized residuals/annual precipitation" it plots residuals against river flow Plot of this kind is used to identify some pattern. It shows somewhat slight positive autocorrelation near value of 500 annual precipitation. That may be due to presence of outliers in data.



The chart " Pred(Flow)/flow" is used to identify the outliers there are two values outside the CI and these are outliers that are the river flows of more than 4500 mcm and near to 6000 mcm. These periods must be identified for detailed study about what actually happened.

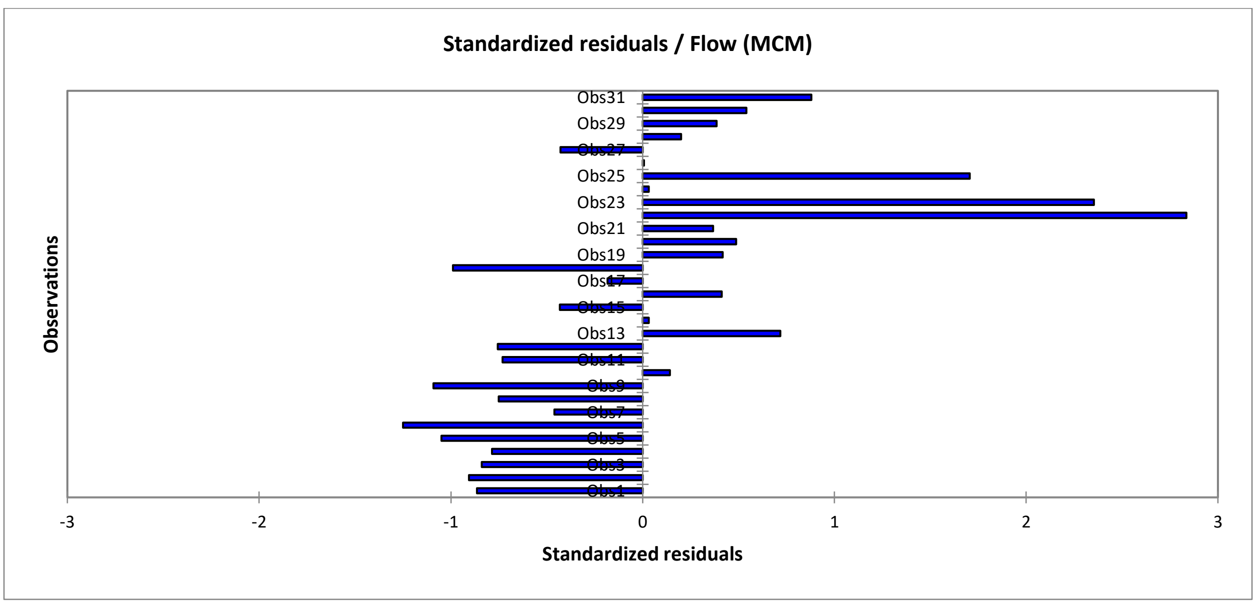
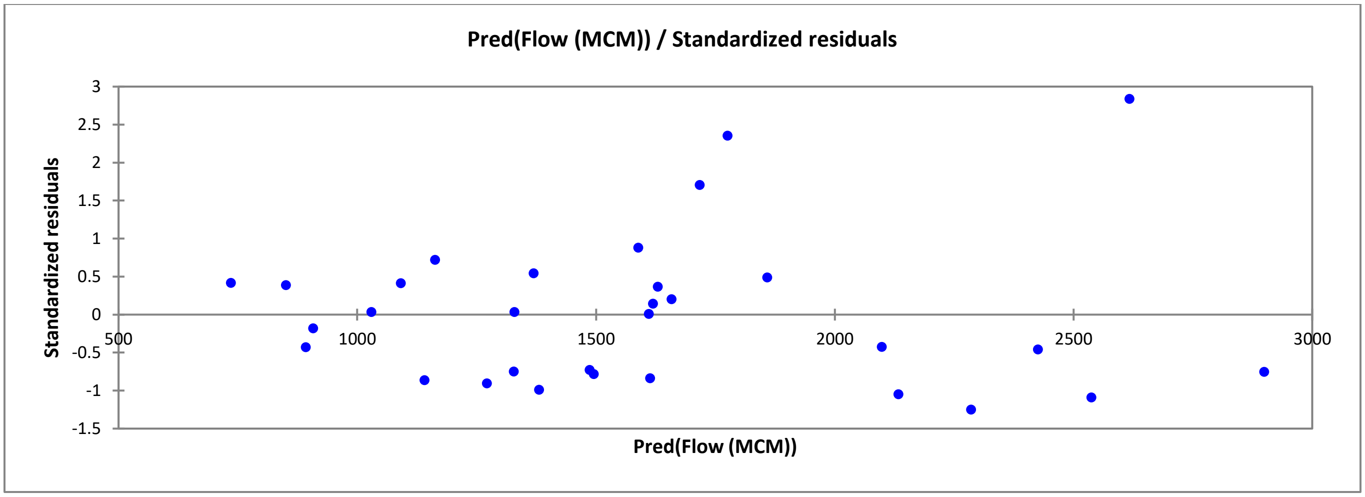


Chart for histogram of residuals represent the unexplained observations outside the range (-2 2) i.e. 95% CI. Here are two frequencies in this range.



Plot for "Pred(Flow (MCM)) / Standardized residuals" shows that as dependent variable increases residuals or unexplained variation will also increase)

Step 4: Generated Flow equation that is used to estimate the projected runoff for different climatic scenarios:

$$Flow\ (MCM)\ =\ -196.91795 + 3.85914 * annual\ precipitation\ (mm)$$

This equation shows that 1mm change in annual precipitation will bring 3.85 units change in river flow. We converted the monthly precipitation of both climatic scenarios to annual precipitation and used in this equation to generate time series of runoff.

These runoff changes must be converted to consistent changes in precipitation, so rough relationships between changes in runoff and rainfall (such as that depicted in Figure 21 for the RCP 4.5 & Figure for the RCP 8.5 scenario) were derived for the catchments. A linear regression model was fit to these data in order to approximate the precipitation changes that would be consistent with the runoff changes being examined:

$$Flow\ (MCM)\ =\ -196.91795 + 3.85914 * annual\ precipitation\ (mm)$$

$$\Delta R = 3.85914 * Annual\ Precipitation(mm) - 196.91795 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. EQ. 3$$

Where,

ΔR = change in runoff;

And ΔP = change in precipitation.

Figure 17: Change in precipitation and runoff projected for 2100 using the linear regression model analysed for the RCP 4.5 Scenarios:

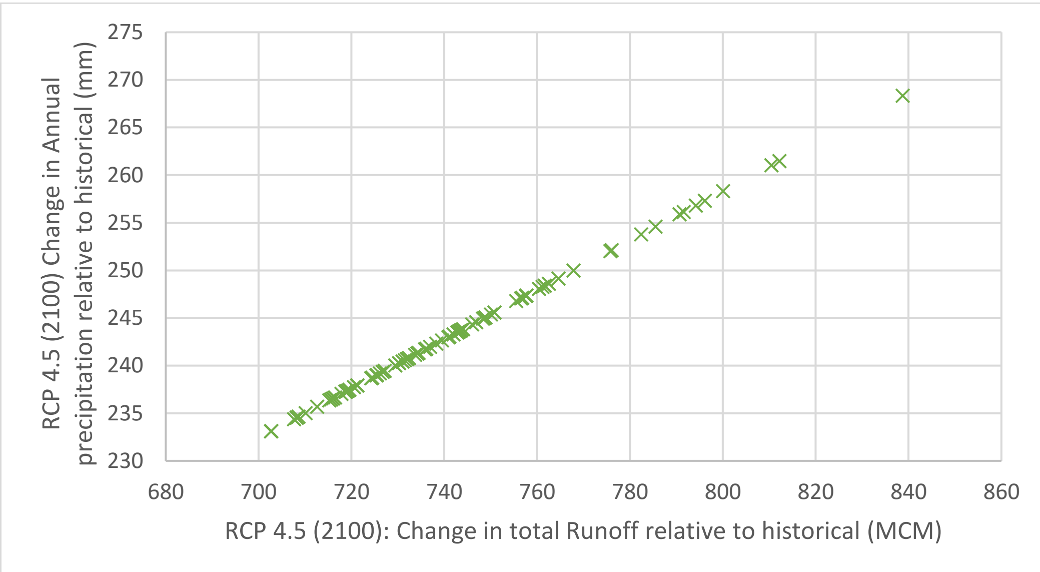
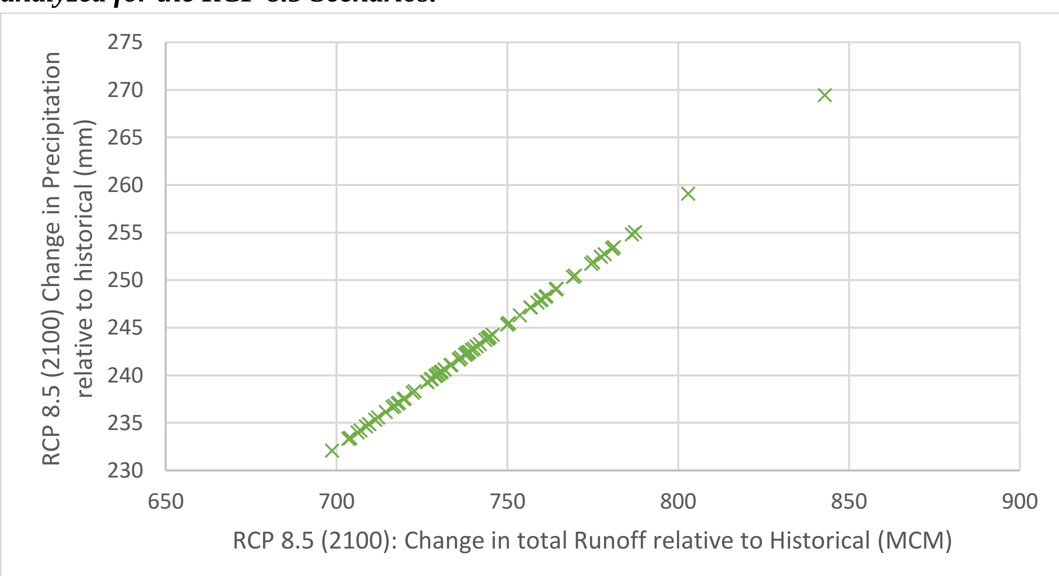


Figure 18: Change in precipitation and runoff projected for 2100 using the linear regression model analyzed for the RCP 8.5 Scenarios:



This approach is admittedly simplistic (changes in runoff will also relate to changes in temperature and evaporation, and will not be the same for different land use types). We only include one factor (e.g precipitation) and analyse its relationship with runoff. The choice of 10 and 20 percent increases is thus not made based on model projections but rather serves to study the extent to which changes in variability could affect this system.

All climate scenarios include the full set of modelled hydrological and economic climate change linkages. RCP 4.5 and 8.5 projections for the year 2100 were used (rather than other available projections for 2030 or 2050), because this date corresponds most closely to the midpoint of the assumed base case project time horizon of 100 years used in the economic analysis of the new weir structures projects and the other reason is that the new climate projections based on only 2100 years. The projection of 2030 and 2050 years are available in AR(4). Extensions of this work could investigate projections for other common dates, or the other two RCP's for example 2030 or 2050 or RCP 2.5 or 6.

Approach:

In the interest of most clearly demonstrating the consequences of the system-wide changes associated with the different water withdrawal conditions and climate scenarios, I use the following approach. Using the longest complete historical flow series available in the basin (1986-2016), water flows at Mithri weir are calculated. Use of the historical series is advantageous because it is easier to interpret for those familiar with the Nari River. Specifically, we can use this series to see how the system's water balance responds to climate change relative to the historical case, rather than a hypothetical "historical" water balance based off of a larger set of stochastic flow experiments. It will also usually be simplest to speak of this water balance in terms of an indicator representing net inflows to Nari River. This indicator is defined as the difference between inflows from the upstream system into the river and the sum of water withdrawals in Kachhi district. Changes in the water balance at this reservoir tend to more smoothly reflect system surpluses or deficits over time. By studying how net inflows to the river respond to changes in climate and water withdrawals, we can understand in different modeled situations whether the system remains "in balance" or not, i.e. whether it is possible for her to maintain her allocation of 120 cusecs for sibi and a positive flow for other areas on a long-term basis.

In referring to a particular combination of scenarios and conditions, the label for the climate scenario comes first followed by the one for the development condition, for the following situations: 1) status quo withdrawals with historical climate H_D0 (Section 6.2); 2) two water withdrawal conditions with increased irrigation and historical climate H_D1 and H_D2 (Section 6.3); 3) status quo withdrawals under various climate change scenarios, focusing on R4_D0 (Section 6.4); and 4) increased development with climate change, especially R4_D1 and R4_D2 (Section 6.5). In the first two steps of this procedure, no changes are made to the historical flows being routed through the Nari River system. In the third and fourth, however, the changes in runoff are made from the climate model projections are applied directly to each annual value in the historical inflow series.

5.13 Results:

Table 5.13: Available water Resource and Target Water Demand at Nari River from last 30 years:

Particular	H_D0	H_D1	H_D2	H_D3
Available water resource:				
Surface water (Flood & Runoff) at Kachhi district (Billion cubic meter)	49.54	49.54	49.54	49.54
Water Use/Target Demand:				
Surface water (Flood & Runoff) at Kachhi	12.54	15.675	19.31 (+0.50)	25.08 (+1.0)

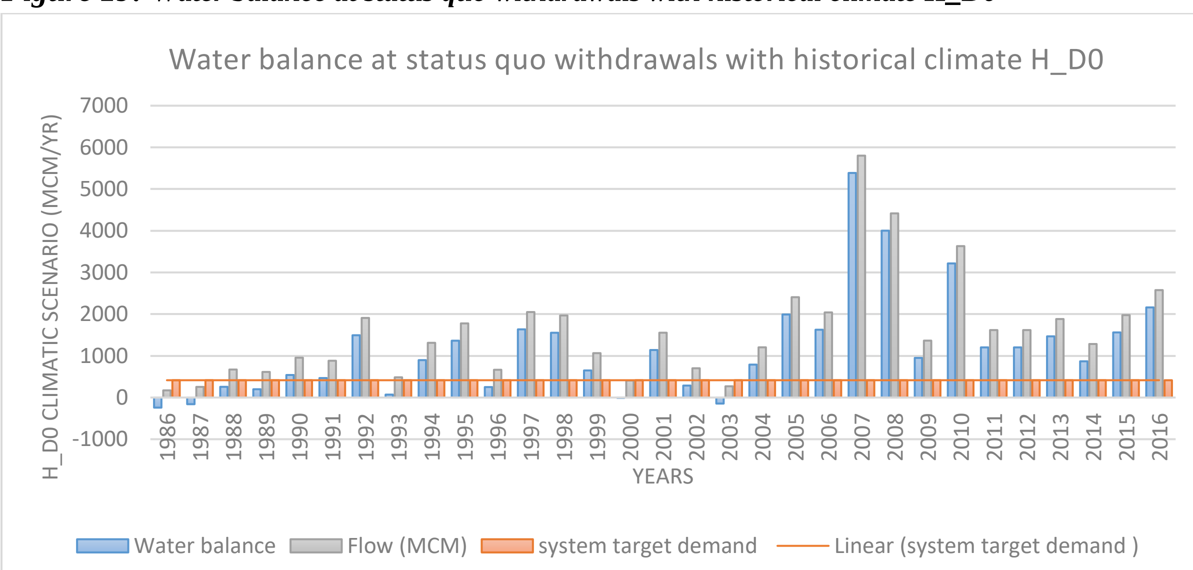
district (Billion Cubic meter)		(+0.25)		
Losses:				
Surface water (Flood & Runoff) at Kachhi district (Billion Cubic meter)	37.00	33.865	30.23	24.46

Source: Irrigation and power department, 2016

Current Development/ Irrigation demand and Historical Climate:

The water balance of the Nari River system, measured in terms of the River flow at Mithri weir, has been discussed in pre-feasibility study; calculations of it formed the basis for the water allocations specified before. From perennial flow 120 cusecs is given to district Sibi. In above results we only discussed the Non-perennial flow. From 1986-2016 data, a total flow of 49.54 bcm are generated from Nari River out of which only 12.54 bcm are utilized for agriculture. Calculation suggest that 37 bcm is lost because no storage facility is available at Kachhi district. Annually almost 1.23bcm water wasted.

Figure 19: ***Water balance at status quo withdrawals with historical climate H_D0***



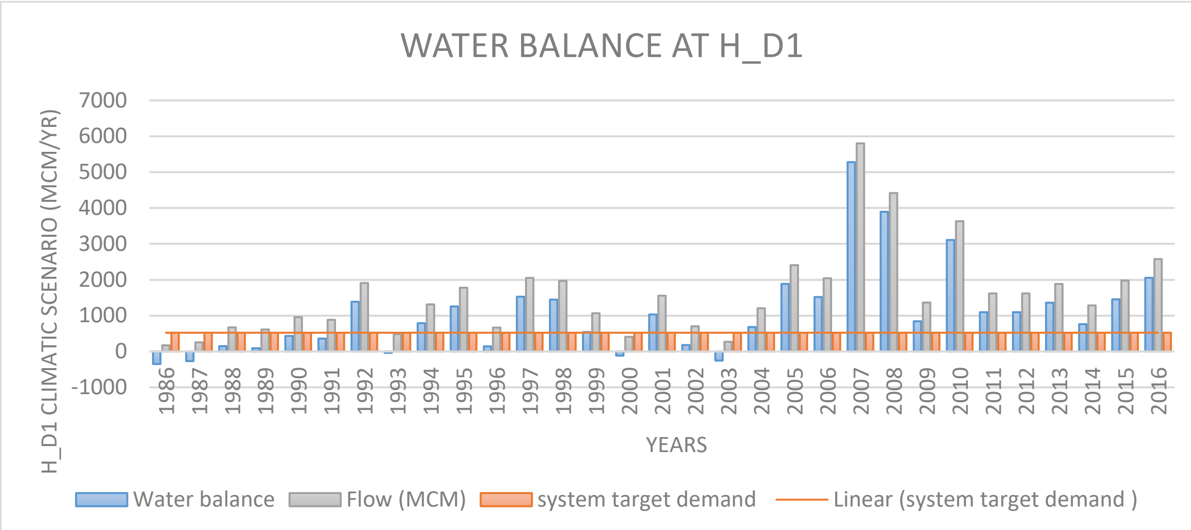
In this figure we analyze the target demand in mcm/year. From the last 30 years, the maximum target demand from Nari River is 415mcm/ year. The deviation from the target demand is clearly shown in figure. The historical data of river flow in mcm is shown in diagram. In 1986, 1987 &

2003 the Nari River is not been able to fulfil the target demand of water and shows a deficit of ~300mcm in water demand. In 2003 Baluchistan experienced severe drought and the water balance is the lowest in this year. From 2007 to 2010, Baluchistan experienced extreme flood event. In these years the water balance is positive because target demand is met. But the water wastage is higher in this year because the storage facilities is not available.

The Effect of Increased Development/ Irrigation demand and Historical Climate:

What happens to this water balance when the community living near Nari River increase irrigation withdrawals to D1, D2 and D3 levels? Under these conditions, the existing surplus at Nari River which is already a loss a reduction is observed under these losses (Table 15). As shown, the losses at Nari River changes from -37 bcm for status quo demands to -33 bcm, to 30bcm and -24 bcm in the three respective conditions from last 30 years. However, in all above cases Nari River is still able to satisfy its demands in all years of the simulation. There are reasons why this is the case. The target demand is lower because of the insufficiency of existing storage structures and the seasonality of flows. The water available during flood period utilized only one time and the access get wasted so people are not able to irrigate the larger areas of lands. In other words we can say that the Nari River is not able to fully satisfy all target demands, because of the insufficiency of existing storage structures and the seasonality of flows. For example, in H_D2, Kachhi district plans for irrigation increase to 19.0 bcm, but she is able to satisfy 49.54 bcm of those demands. Thus Kachhi district would have to invest in storage in order to reach these target demands. The increased target demand is favoured by the historical hydrological conditions but only when investment would be made in large storage structures. Otherwise the loss of water from last years is very much higher of about 37 bcm in the H_D0 scenario.

Figure 20: Water withdrawal conditions with low development and small increase in irrigation with historical climate H_D1



Under water withdrawal D1 scenario, the target water demand is 523mcm/ year if irrigation in the area increased by 25%. On the basis of historical data, water balance is determined, which shows a deficit of water in years 1986,1987,1993,2000 & 2003. On D0 target demand level the deficit in observed in only three years. However the increasing irrigation demand will be fulfilled by the historical water flow. By increasing target demand, in deficit years, the loss will be ~400mcm/year.

Figure 21: Water withdrawal conditions with moderate development/ increase in irrigation with historical climate H_D2

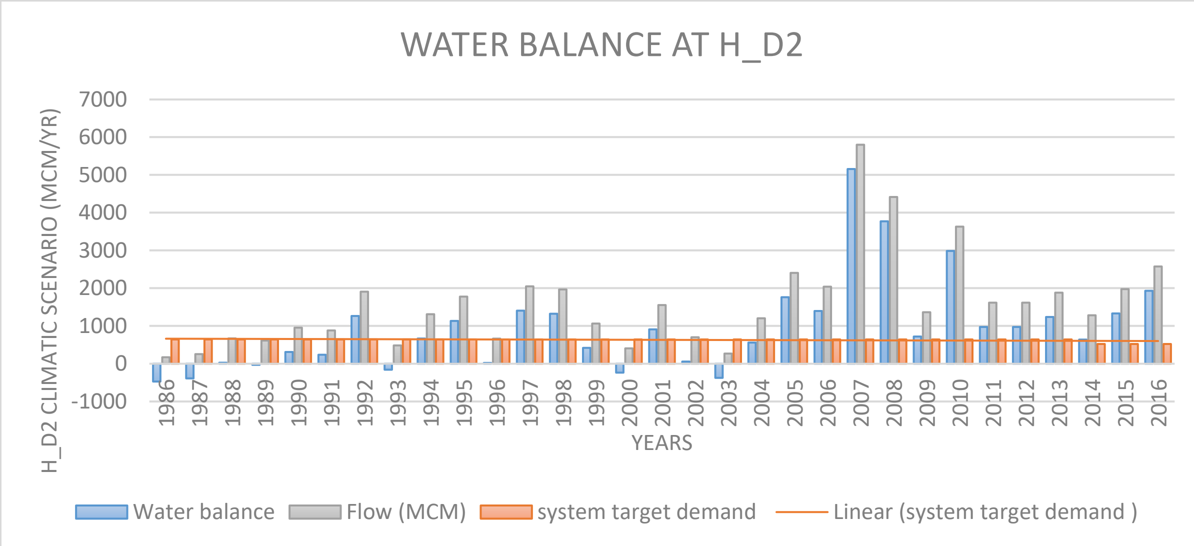
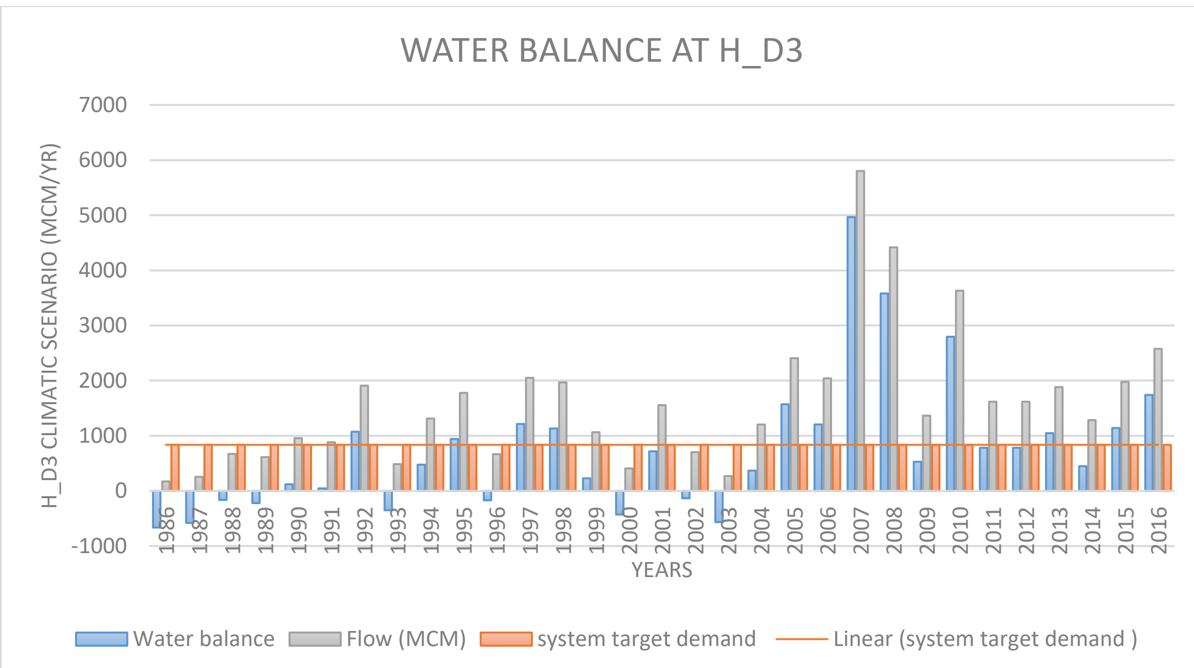


Figure 22: Water withdrawal conditions with high development/ large increase in irrigation with historical climate H_D3



Under water withdrawal D2 & D3 scenario, the target water demand is 623 mcm/year in D2 scenario and 836mcm/year in D3 Scenario. If the development of the economy is moderate and irrigation in the area increased by 50%. On the basis of historical data, water balance is determined, which shows a deficit of water in years 1986, 1987,1988,1993,2000 & 2003. On D0 target demand level the deficit in observed in only three years. However the increasing irrigation demand will be fulfilled by the historical water flow. By increasing target demand, in deficit years, the loss will be ~600mcm/year. In case of high development and large increase in irrigation occurred the water deficit in each year would be higher. On the basis of historical data, water balance is determined, which shows a deficit of water in years 1986, 1987, 1988, 1989, 1993, 1996, 2000, 2002 & 2003. On D0 target demand level the deficit in observed in only three years. However the high increase irrigation demand will be fulfilled by the historical water flow but only in few year. By increasing target demand because of high development, in deficit years, the loss will be ~800mcm/year.

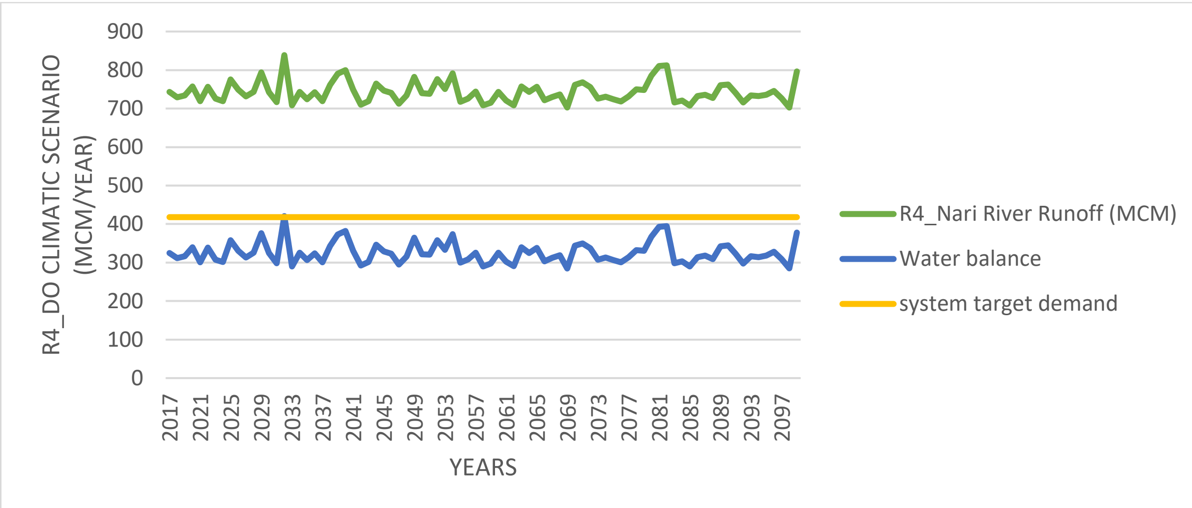
The effect of climate change with the baseline withdrawal condition:

The next step of the analysis is to evaluate how climate change might affect these water balance calculations. We first consider the system in the D0 development condition and R4 climate scenario. In studying this R4_D0 situation, we proceed by adding different aspects of climate change one at a time. We start with the projected runoff changes in the Nari River, and add the physical climate linkages individually and together to obtain the cumulative effect of the R4 scenario on the water balance. In this way, we can observe how the various linkages affect the system. The analysis concludes with a sensitivity analysis a) using the bounds of the inflow sensitivity scenarios (I-20_D0 and I+20_D0), and b) the second IPCC scenario (R8_D0).

The R4_D0 Analysis:

Year wise analysis for R4_D0 shown in Figure 23. The project runoff for the next 2100 years is very much lower as compared to historical data. The projected runoff will be enough to meet the current water demand level of 418mcm/year. If the target demand remain same then the projects benefit will be positive because with the climate change the Nari River generate a positive water balance of ~300 to 400mcm/year and the current demand of irrigation will be easily fulfilled.

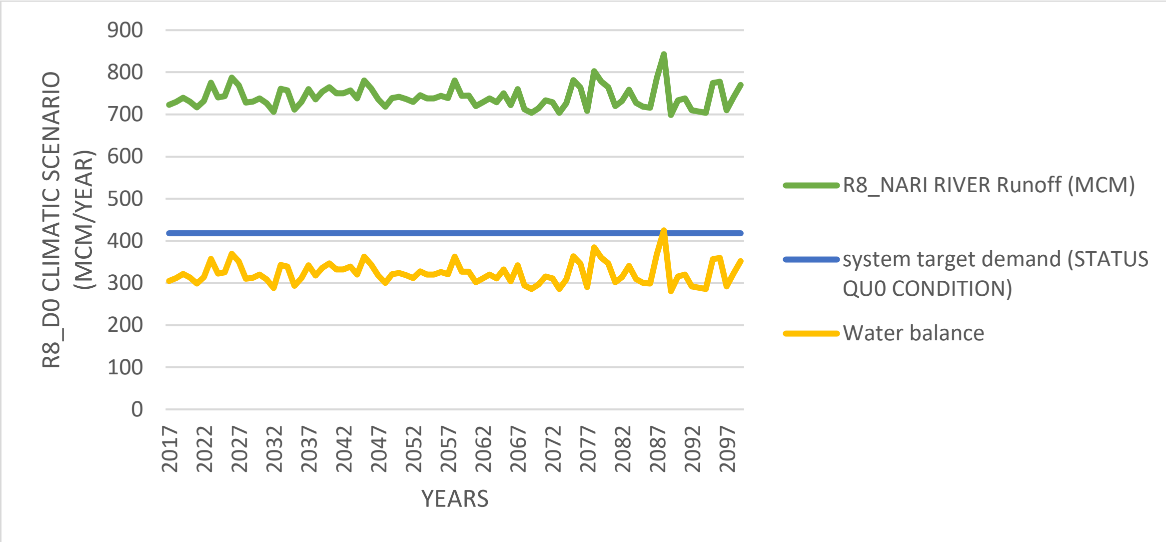
Figure 23: Current water withdrawal comparison with project runoff at climatic scenarios 4.5



However, we knew that previously the land irrigation is lower because of non-availability of water and the project estimate that the land area would increase in future which will result in increased demand of water. So it seems critically important to analyze whether the project R4 scenario runoff will meet that increased demand. To analyze this we will use the R4_D3 scenario which shows high irrigation or development in area (see sensitivity analysis section)

The R8_D0 Analysis:

Figure 24: Current water withdrawal comparison with project runoff at climatic scenarios 8.5



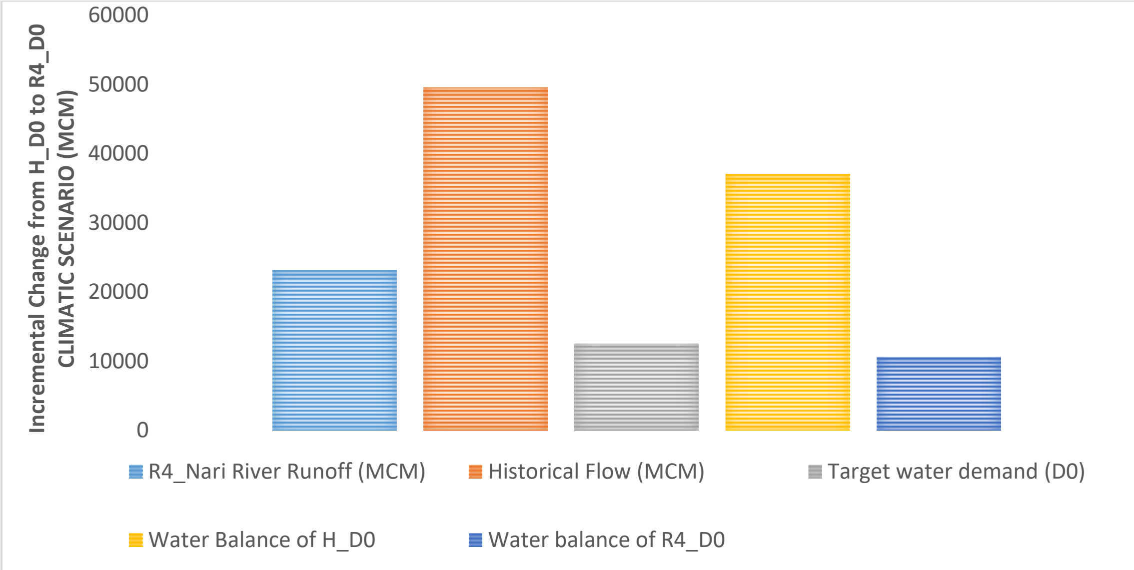
In climatic scenario R8, the projected runoff lies within the range of 700-800mcm/year. If the target demand remains at the level of 418 per year. The current irrigation demand will be met by projected runoff of climatic scenario R8. We will experience the positive water balance. This means that increasing irrigation demand will be possible (but up to what extend analyze this in later section)

5.14 Comparative analysis:

Comparison between R4_D0 & H_D0:

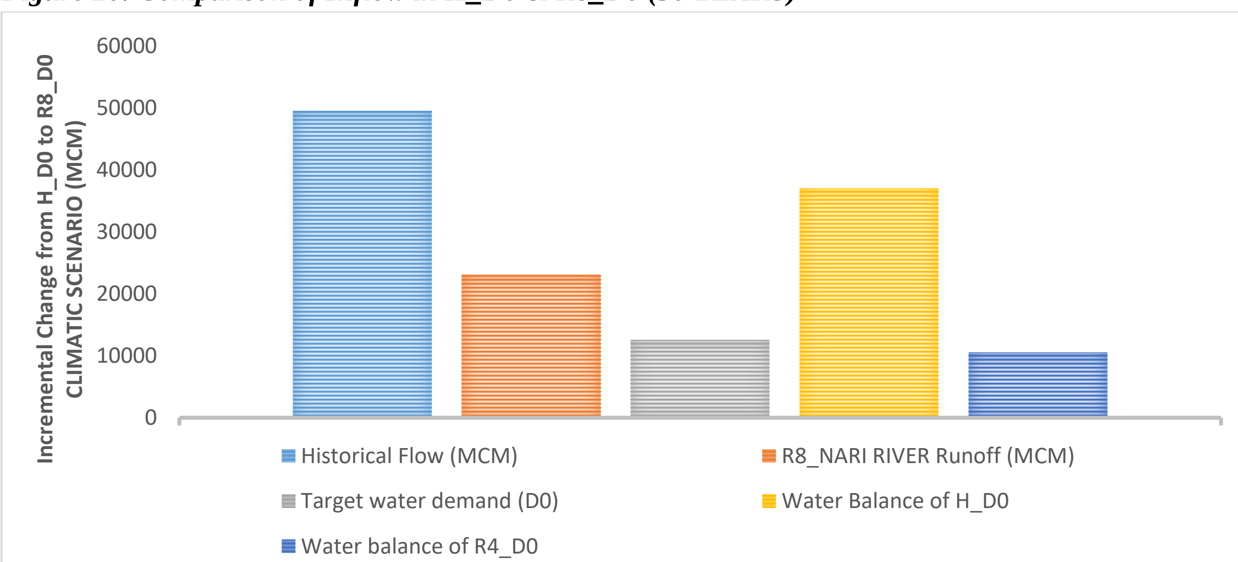
The R4_D0 experiment shows that the largest change in water balance for this system is associated with changes in climate (Figure 25). The R4_D0 runoff changes result in an increase in the level of precipitation due to higher emissions. The R4_D0 runoff is lower as compare to H_D0. The sum of runoff of last 30 years and sum of runoff of projected runoff from climatic scenario RCP 4.5 is compared. The reduction in runoff is ~26,438MCM (which is almost half of the last 30 years runoff). Water surplus that are lost in previous years was double than the surplus generated in future (2047). The target water demand at D0 level is fulfilled in both scenarios and generate a positive balance.

Figure 25: Comparison of Inflow in H_D0 & R4_D0 (30 YEARS)



Comparison between R8_D0 & H_D0:

Figure 26: Comparison of Inflow in H_D0 & R8_D0 (30 YEARS)



The R8_D0 experiment shows that the largest change in water balance indicators for this system is associated with changes in runoff (Figure 26). The R8_D0 runoff changes result in an increase in the level of precipitation due to higher emissions (R8 shows highest level of CO2 emission as compare to R4). The R8_D0 runoff is lower as compare to H_D0. The sum of runoff of last 30 years and sum of runoff of projected runoff from climatic scenario RCP 8.5 is compared. The reduction in runoff is ~26,486 MCM (which is almost half of the last 30 years runoff). Water surplus that are lost in previous years was double than the surplus generated in future (2047). The target water demand at D0 level is fulfilled in both scenarios and generate a positive balance.

However, if we make a comparative analysis between R4_D0 & R8_ D0 we will find out that the water balance of both climatic scenario is almost same. The reduction of runoff as compare to H_D0 for R4 is ~26,438MCM and for R8 it is ~26,486 MCM. The difference between these two scenarios is smaller. However, the difference is larger/double when make comparison with historical river flow.

Figure 27: Water Balance Under Different Climatic Scenario (comparison of projection and historic data)

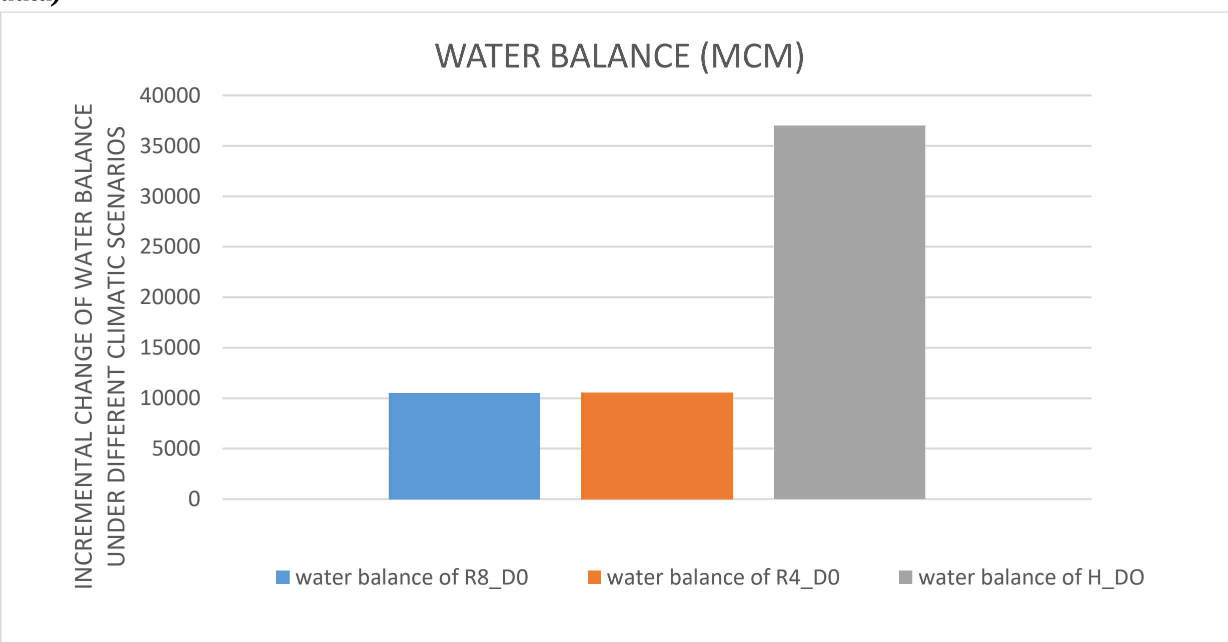
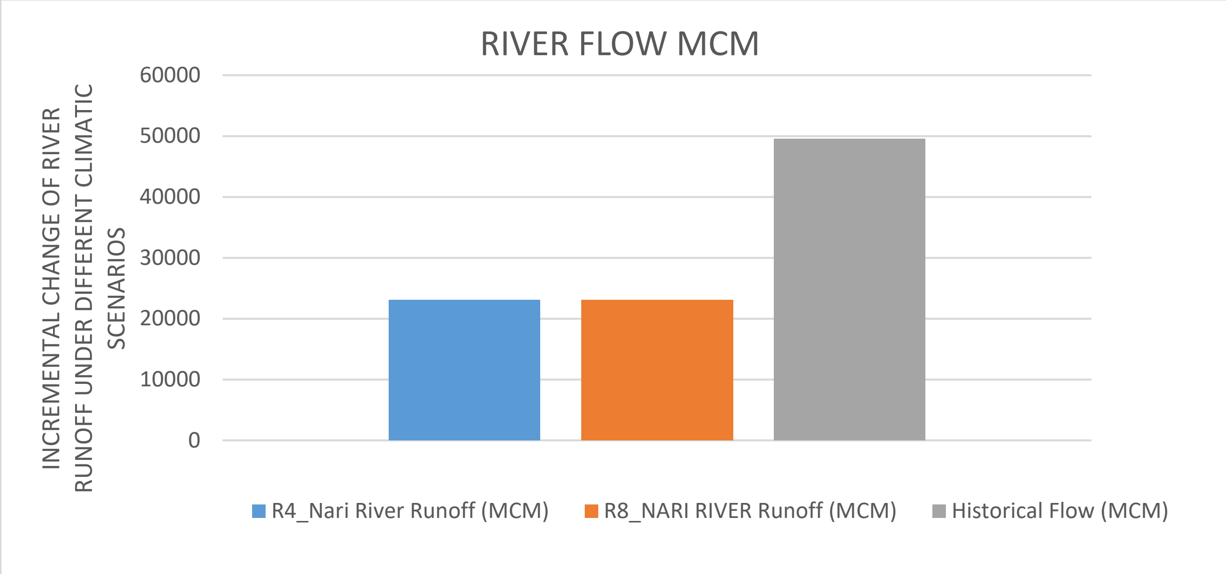


Figure 28: Comparison of River Flow Under Different Climatic Scenario (comparison of projection and historic data)

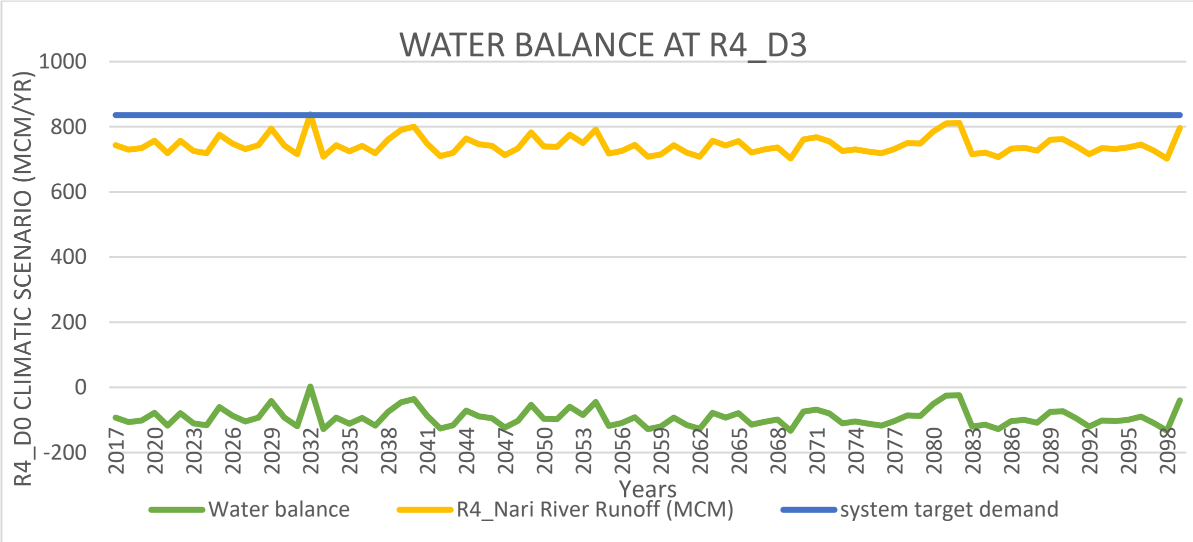


5.15 The effect of climate change with the moderate or high withdrawal condition:14

The R4_D3 Analysis: The R4_D3 experiment shows that the largest change in water balance indicators for this system is associated with changes in runoff (Figure 29). The R4_D3 runoff changes result in a deficit in all 2100 years at high target demand (because of availability of storage facilities). A deficit of minimum -133mcm/year is expected to be incurred at higher projected demand. Minimum of -0.13 bcm/yr is expected. However, in H_D3 scenario the water deficit is incurred in few years and in 2007-2009 it shows positive balance with high target demand. In R4_D3 a minimum of -0.13 bcm/yr reduction from the +1.05 bcm/yr H_D3 surplus found at Nari River. Levels in the reservoir would therefore drop to a new, lower equilibrium if releases of 0.836 bcm/yr were maintained.

[14] Here we only show results of climatic scenario 4.5 the climatic scenario 8.5 results shows in Appendixes because the results is almost same as rcp 4.5. The deficit in water balance realized in only high irrigation demand. If you want to go through these results as well see appendix.

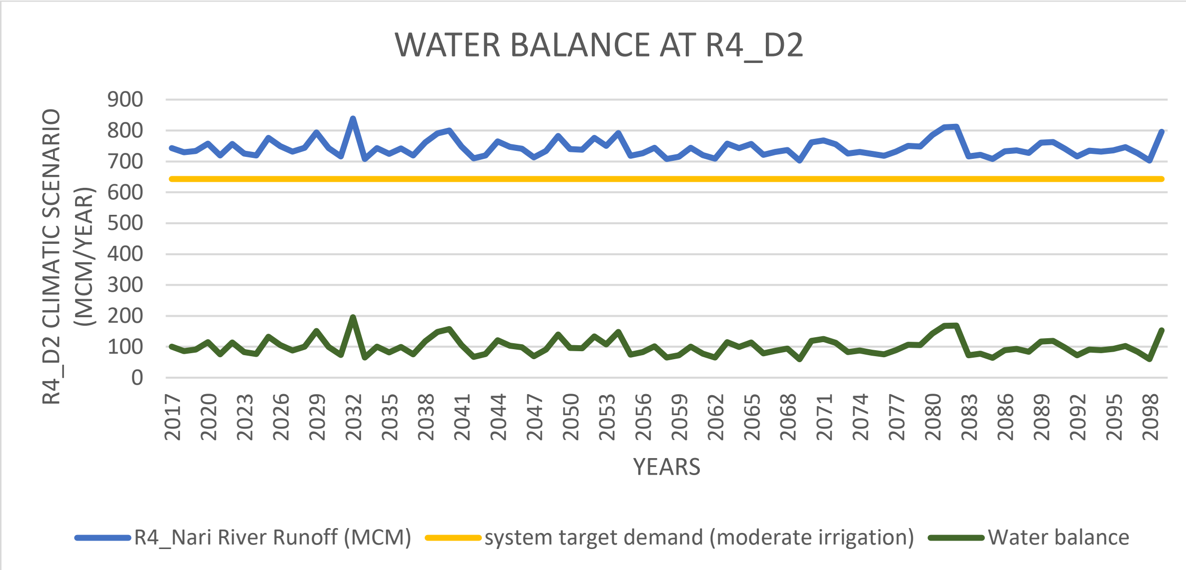
Figure 29: Water balance in Climatic Scenario RCP 4.5 and High Irrigation Demand



The R4_D2 Analysis:

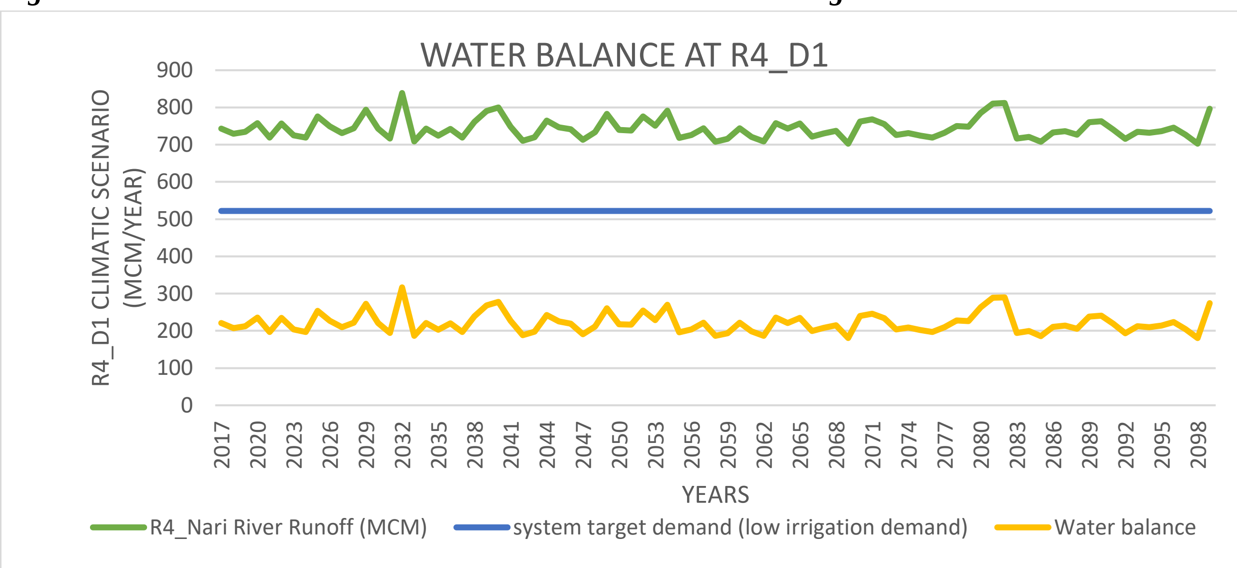
The R4_D2 experiment shows that the largest change in water balance occur because of changing climate as well as the irrigation demand (Figure 30). The R4_D2 runoff changes result in a surplus (but lower amount) in all 2100 years at moderate irrigation target demand (because of availability of storage facilities). A surplus of minimum 60 mcm/year is expected to be incurred at moderation irrigation projected demand. However in R4_D2 scenario the water surplus is incurred in all years. In R4_D2 a minimum of 0.06 bcm/yr surplus found at Nari River.

Figure 30: Water balance in Climatic Scenario RCP 4.5 and moderate Irrigation Demand



The R4_D1 Analysis:

Figure 31: Water balance in Climatic Scenario RCP 4.5 and low Irrigation Demand



The R4_D1 experiment shows that the largest change in water balance occur because of changing climate as well as the irrigation demand (Figure 31). The R4_D1 runoff changes result in a small amount of surplus (but higher than the R4_D2 scenario) in all 2100 years at low irrigation target demand (because of availability of storage facilities). A surplus of minimum 90 mcm/year is expected to be incurred at low irrigation projected demand. However, in R4_D1 scenario the water surplus is incurred in all years. In R4_D1 a minimum of 0.09 bcm/year surplus found at Nari River.

Sensitivity analysis:

We next consider the sensitivity of these water balance calculations to assumptions about climate change, first across a wider range of inflow changes (-20% and +20%) coupled with the R4 scenario changes (in precipitation), and second in the R8 scenario. scenario. Below table presents a tabular comparison of the water balance calculations for these scenarios.

Table 5.14: Sensitivity analysis of the effect of climate change on the Nari River water balance with all level of irrigation target demand (D0, D1, D2, and D3):

Climatic Scenarios	**R4**	**-20%**	**-10%**	**+20%**	**+10%**	**R8**	**-20%**	**-10%**	**+20%**	**+10%**
Flows:	743	594	668	891	817	741	592	666	889	815
Target irrigation demand:										
Status quo Irrigation										418
Low Irrigation										525
Moderate Irrigation										543
High Irrigation demand										836
Water Balance*										
D0	325	176	250	473	399	323	174	248	471	397
D1	218	69	143	366	292	216	67	141	364	290
D2	200	51	125	348	274	198	49	123	346	272
D3	-93	-242	-168	55	-19	-95	-244	-170	53	-21

* Surplus/deficit in each situation

In above mention table we conduct the sensitivity analysis by reducing or increasing the flow level by 10% and 20%. These values are selected on the basis of historical and future flow data. The rate of change in flow in future projections are maximum of 9.7 however in historical data the deviation in each year is very much different because we experience severe drought and flood. The mean change in flow is 25.3. We will select on data basis because no literature/baseline is available. As mentioned above, the choice of 10 and 20 percent serves to study the extent to which changes in variability could affect this system. Through sensitivity analysis it has been analyzed that the water deficit in all situation has been analyzed even with increasing flow up to 20%. If flow were reduced more substantially, system demand deficit would become more substantial in the high irrigation development scenario. However, moderate irrigation is possible in all climatic scenarios. But in moderate irrigation the benefits will only be higher when water utilization is comprehensive. High withdrawals (D3) would present greater difficulty for the Nari River riparians. From a climate change perspective, it would appear to be exceedingly risky for the Nari riparians to embark on this high development path. Increased inflows could allow moderate irrigation.

Summary:

This chapter presented calculations of the water balance in the Nile system under various climate scenarios and water withdrawal conditions. The calculations showed that the system water balance is sensitive to assumptions about both climate change and development. In terms of climate change, very few researches has focused either on changes in runoff alone, or on the need for greater water use for existing cropping systems, rarely studying the effects of both processes together. We saw in this chapter that the effect of climate change is complex and involves feedbacks between water flows and water withdrawals. Several aspects of climate change were shown to be important in changing the water balance in the Nari River Basin. The system water balance appears particularly sensitive to large decreases in runoff. The water balance calculations showed that the river runoff would be higher in historical condition at Nari River in every targeted demand level. However, we can also see that unless “water-saving” projects such as the Nari River project are not implemented in kachhi district, most of this additional water will be lost. But the river runoff in future can only fulfil the demand at low/moderate level of irrigation. At high level of irrigation demand, the result would be deficit in water balance. So project description that the irrigation in Kachhi district will increase at larger scale cannot be fulfilled at R4_D3 and R8_D3. The effect of the R4 and R8 climate scenario is thus to decrease the balance of inflows to Nari River, primarily via lower runoff. It should also be clear from the calculations that irrigators in the Nari River basin will need to develop strategies for confronting decrease in runoff (if they want to increase their target demand from the current level). The agriculture sector could address demand shortfalls in a number of ways, perhaps investing in more efficient irrigation technologies, introducing water prices to promote efficiency in water use, encouraging farmers to alter the cropping mix to include less water-intensive crops, or restricting irrigation via other means. One interesting point in results, that in Historical climate we face water balance deficit in many years in all water withdrawals condition however the runoff is reduced in future climatic scenarios but the deficit is only analyzed at R4 _D3 and R8_D3. This is because the future projection shows a stability in runoff however in historical data we experienced the instability in flow and two climate stressors affect drought and flood. The deficit is experienced in drought period. The water balance is lower in both climatic projection as compared to the historical water balance. The loss of water wastage is higher in past then what we save in future now. Furthermore, it was shown that the system could not easily handle increases in withdrawals coupled with significant reductions in flow (say 10 to 20%). Indeed, system runoff reductions of 20% or more would create very significant water stresses if additional irrigation projects are pursued. The riparians' individual goals for full irrigation development appear to only be possible if inflows increase in the basin in the future, or if other means of saving substantial amounts of water are pursued.

5.16 Results of the economic simulations: the effects of hydrological and economic parameter uncertainty:

Economic Aspects of Research:

To analyze the value of weir structure project through simulation we first develop the model logic in a usual way which we use some excel tools and not risks. This would be completed in a financial model first. This model is the starting point for the @risk analysis. The value we are interesting in analyzing (e.g NPV) our bottom line will become the output cell in @risk. The values that are uncertain (e.g all costs and benefit) will become the input cell in @risk. In this research, we are evaluating the water resource investment project. There is initial investment followed by future years of revenue associating variable cost and fixed costs. We project the cash flows for next 10 years to calculate the key measures of project performance the NPV.[15] However there is considerable uncertainties about the cost and future revenue. This mean we cannot be sure about what the NPV would really be. This is where @risk come in. We will see that @risk can help us access the probability of negative NPV, Positive NPV and more. We will also be able to uncover which of the uncertain input contribute most to NPV. This is the information that might help us choose the most profitable strategies.

Table 5.15: selected certain and uncertain input and output cells parameter

Known inputs	Value
Discount rate	4 [2-6]*
Weir Structure Project Duration	30 [20-80]*

*In parentheses, uncertainty range of each uncertain parameter is defined.

Uncertain Inputs/Economic Parameters	Value	Distribution

[15] NPV based on cash flows, the initial Investment and the discount rate. Our model only includes the one output cell which is NPV. The model can also include the possibility of Bonus. But in our case the project doesn't specify any possibility of bonus. So we didn't include it.

Investment/capital Costs (Million Rs.)	4912.386 [4666.766-5649.244]	Triangular
Annual operation and maintenance cost (as % of annual capital cost)	2456 [1842-4175.2]	Triangular
Cost of flood protection	71.939 [57.5512 – 128.739]	Triangular
Number of house displacement	0 [0-100]	Uniformly
Benefits of Flood Protection	2.74366 [2.469 – 3.018]	Triangular
Agriculture Revenue	------------------------------*	Triangular
Annual Variable Cost (Million Rupees)	81.08 [72.972- 89.188]	Triangular
Fixed Cost (million Rupees)	3562.18 [2849.744 – 5699.2]	Triangular
Annual Revenue Growth Rate	8.29% [5-8.29%]	Normal
Annual Variable Cost Percentage	0.02 [0.00 -0.02]	Normal

*Agriculture revenue and their uncertainty range differ in different climatic scenarios. Benefit from agriculture was calculated for each scenario on the basis of river flow level.

Output cells	**Value**
NPV	=initial investment +NPV (discount rate, Projected Cash flow)*

*projected cash flow is estimated by using the table 2 parameters (all benefits – all costs)

As mentioned above that the cells in which we are interesting in analyzing is our bottom line cells and in this model the output cells are the NPV (specified in table). @risk won't tell you exactly or certain values for these outputs. This is impossible because future cannot be predicted with certainty. However, as you will see in result section that @Risk can report the probability of different values incur for each output and that information can help you make more important decisions. We can only derive the probabilities of different values when we add the risk element on each of the output cell (on NPV). By doing this the formula of NPV will changed and they now include the risk output function and a plus sign which indicate that this is a @Risk output cell function.

$$NPV = Riskoutput("NPV") + NPV(Discountrate, Cashflow)$$

The corresponding cells are called input cells. In this model the 10 value in the uncertain input are uncertain as mentioned in table. There are many different probability distributions which we can use in @Risk inputs. Here we use 3 common distribution triangular, normal and uniform[16]. All distribution requires to supply parameters. These parameters are the value that describe us the probability distribution such as its central location, its variability and its change. In triangular distribution, the parameters are the minimum value, the most likely value and the maximum value. Shape of this distribution is literally a triangle with the peak at most likely value. Uniform distribution follows the constant probabilities. In a normal distribution the parameters are the mean and standard deviation. This is the traditional bell curve. The mean is the average and most likely value and standard deviation is the measure of variability around the mean. Normal distribution are symmetric meaning the value above the mean are just as likely as the value below the mean. The parameters in our case has been listed at table (they include the most likely value, the minimum value and the maximum value for the eight triangular distribution, and the mean and standard deviation for the two normal distributions).

Climatic Scenario RCP 4.5 & 8.5: Defining Input Distribution

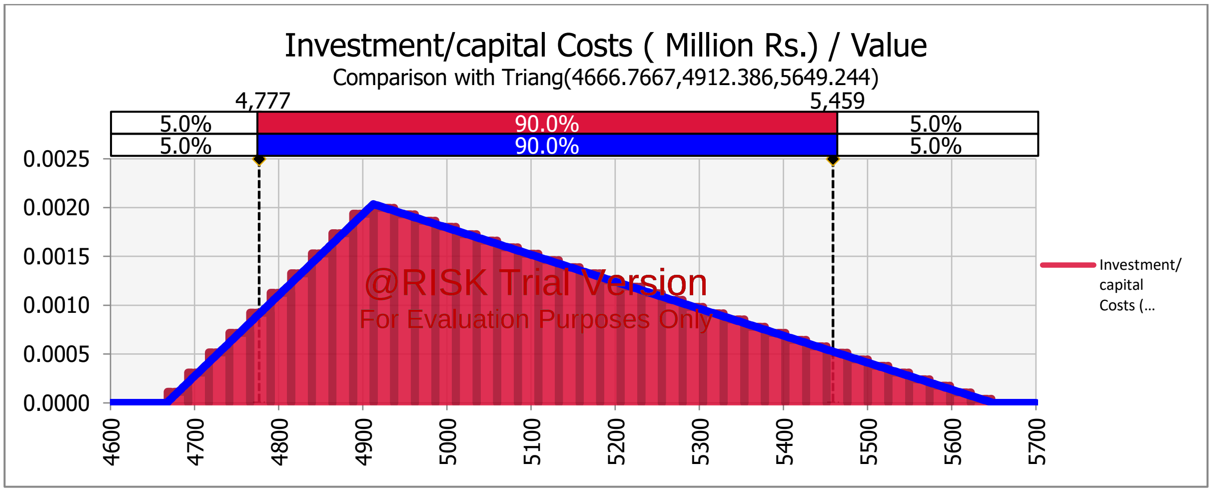
@Risk Input Cells/@Risk input Parameters	Distribution
Investment/capital Costs (Million Rs.)	Triangular
Annual operation and maintenance cost (as % of annual capital cost)	Triangular
Cost of flood protection	Triangular
Number of house displacement	Uniformly
Benefits of Flood Protection	Triangular
Agriculture Revenue	Triangular
Annual Variable Cost (Million Rupees)	Triangular
Fixed Cost (million Rupees)	Triangular
Annual Revenue Growth Rate	Normal
Annual Variable Cost Percentage	Normal

[16] A natural question to ask is where these parameters come from? As in our case we choose the normal distribution is appropriate for the annual revenue growth rate. Where did we get the mean and the standard deviation for this distribution? The answer might be based on the historical data, it might be based on the opinion of expert, it might be based on your own subject of telling about the future, or it may be a combination of all these. This is always a difficult decision but it is important one. We prefer to choose those parameters that are more realistic and based on data.

Discount Rate	Uniformly
Weir Structure Project duration (years)	Triangular

5.17 Results of Triangular distribution:

Figure 32: Triangular Distribution for Investment Cost:



Risk Triangular Function:

$$= RiskTriang(4666.7667, 4912.386, 5649.244, Riskstatic(4912.386))$$

Risk triangular function of the investment cost have its three arguments which are the parameters of this triangular distribution. There is also 4rth risk static argument shown in equation. Is shows that either it is random/static. If we choose random it will generate many different random values. This latter behaviour is the essence of simulation instead of getting a single value in the input cell we will get a range of values determined by the probability distribution we used. In this figure, based on the triangular distribution for the investment cost the most likely value is indeed 4912 Million PKR. But there is some probability that the investment cost will be greater than 5649 Million PKR and there is some probability that it will be less than 4666 Million PKR. Infact every value from 4800 to 5500 has some chance of occurrence. The probability is almost 90% that the values lies within the specified range.

Figure 33: Triangular Distribution for Annual Operation and Maintenance Cost:

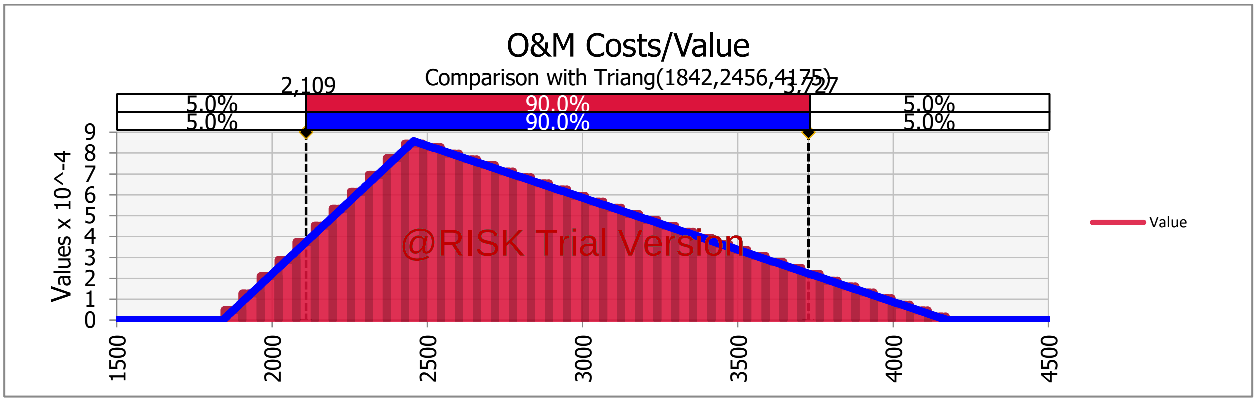


Figure 34: Triangular Distribution for Cost of flood protection:

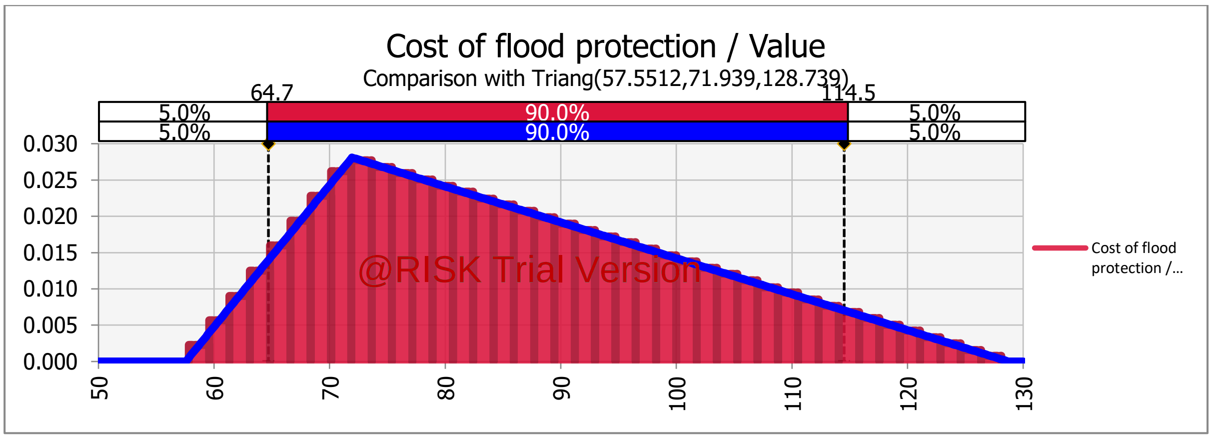


Figure 35: Triangular Distribution for Benefits of flood protection:

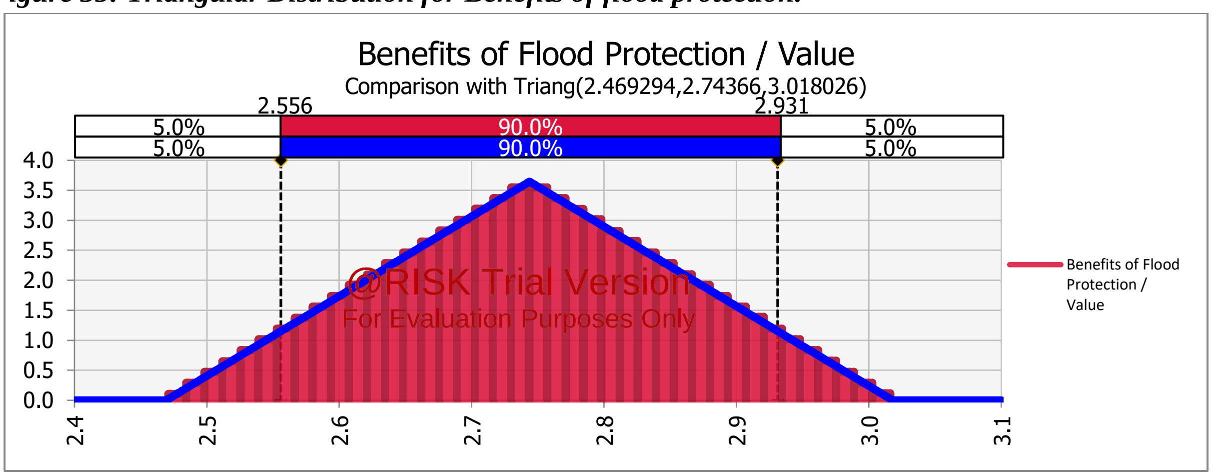


Figure 36: Triangular Distribution for Agriculture Revenue:

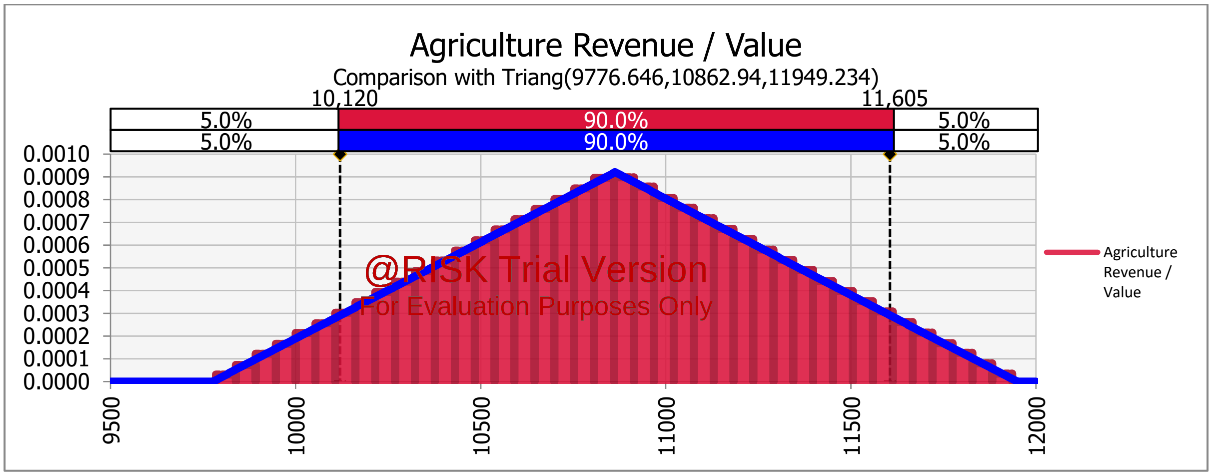


Figure 37: Triangular Distribution for Annual Variable Cost:

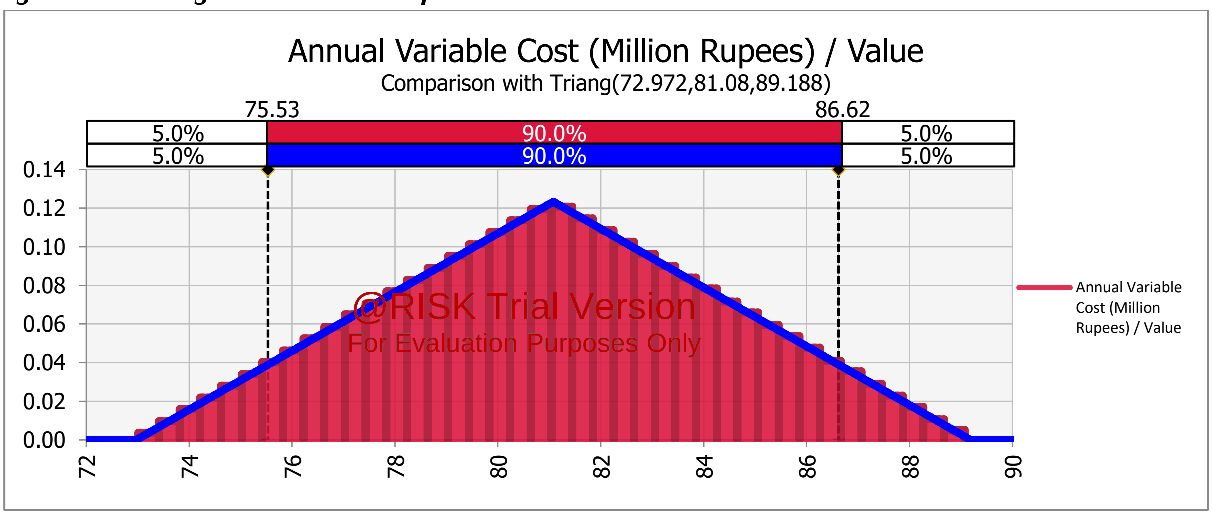


Figure 38: Triangular Distribution for Fixed Cost:

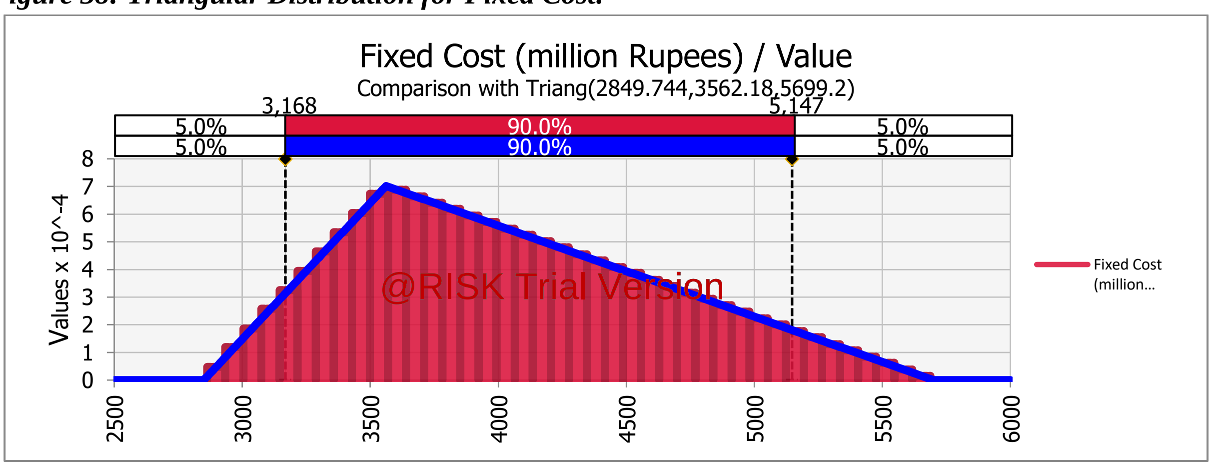
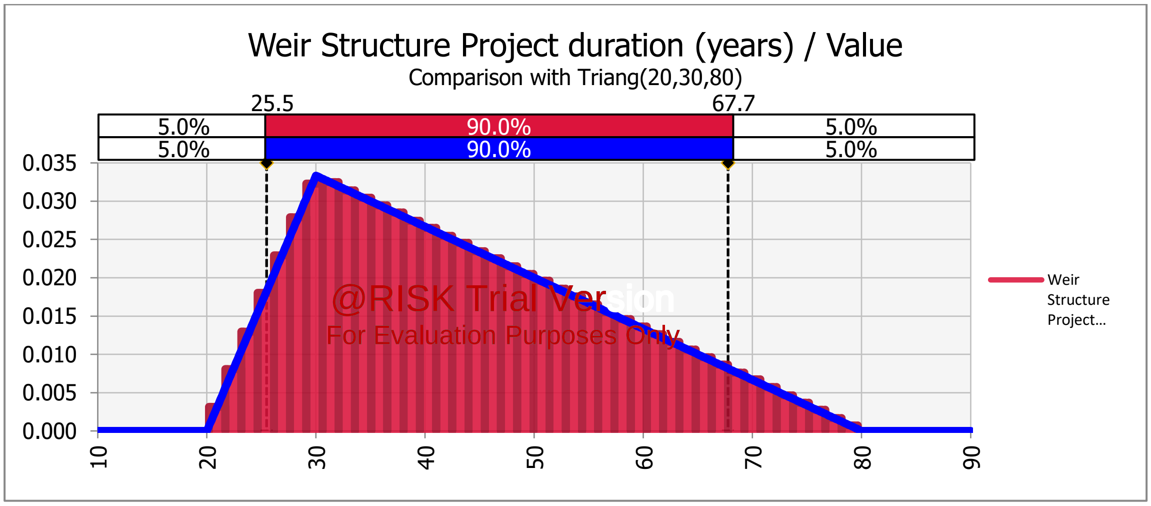


Figure 39: Triangular Distribution for weir structure project duration:



In above all Figures we shows the triangular distribution for the uncertain input (which is the benefits of flood protection, costs of flood protection, weir structure project duration, agriculture revenue, fixed cost, variable cost & operation and maintenance cost). In each figure, the most expected value for each uncertain input variables (costs and benefits) is given. The flood protection cost that is more expected to be incurred is 71.939 Million PKR, for annual operation and maintenance cost is 24.56 Million PKR, for agriculture revenue is 10862.94 Million PKR, for Annual variable cost is 81.08 Million PKR, for fixed cost is 3562.18 Million PKR. The flood protection benefits that is more expected to be incurred is 2.743 Million PKR which also include the reduced/saved cost of community to construct gunda's annually. That cost now becomes the part of benefits. However, there is some probability that the values of uncertain inputs are greater than the specified minimum value and there is some probability that it will be less than the specified maximum values. The minimum value for annual operation and maintenance cost is 20.876 Million PKR, for agriculture revenue is 9776.6 Million PKR, for Annual variable cost is 72.97 Million PKR, for fixed cost is 2849.7 Million PKR, for flood protect costs is 57.55 Million PKR & for the flood protection benefits 2.46 Million PKR. The maximum value for annual operation and maintenance cost is 30.068 Million PKR, for agriculture revenue is 11949.23 Million PKR, for Annual variable cost is 89.18 Million PKR, for fixed cost is 5699.2 Million PKR, for flood protect costs is 128.7 Million PKR & for the flood protection benefits 3.01 Million PKR. Infact every value from minimum to maximum of triangular range has some chance of occurrence. The probability is almost 90% that the values of given uncertain inputs lies within the specified ranges.

5.18 Results of Uniform Distribution:

Figure 40: Uniform Distribution for Discount rate:

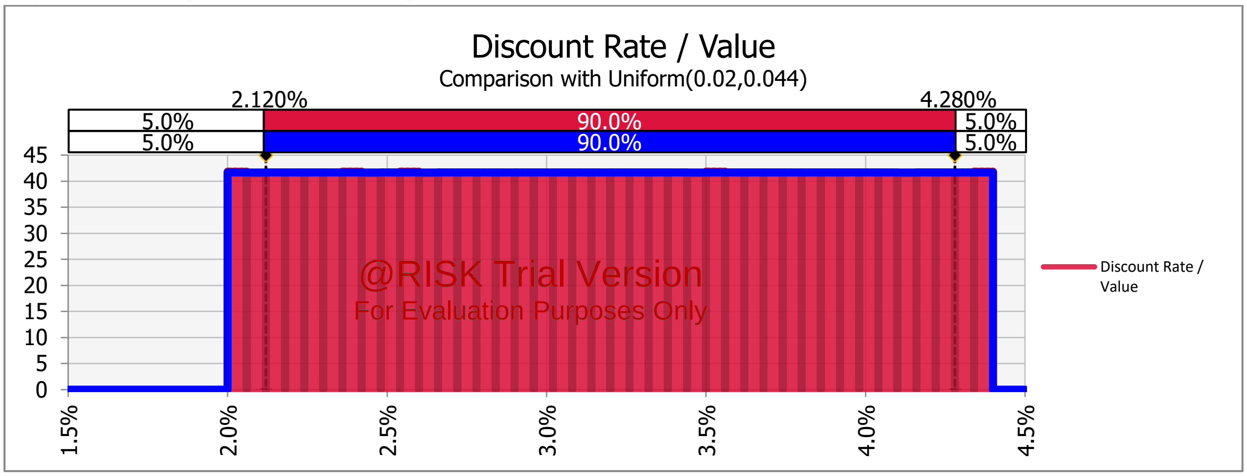
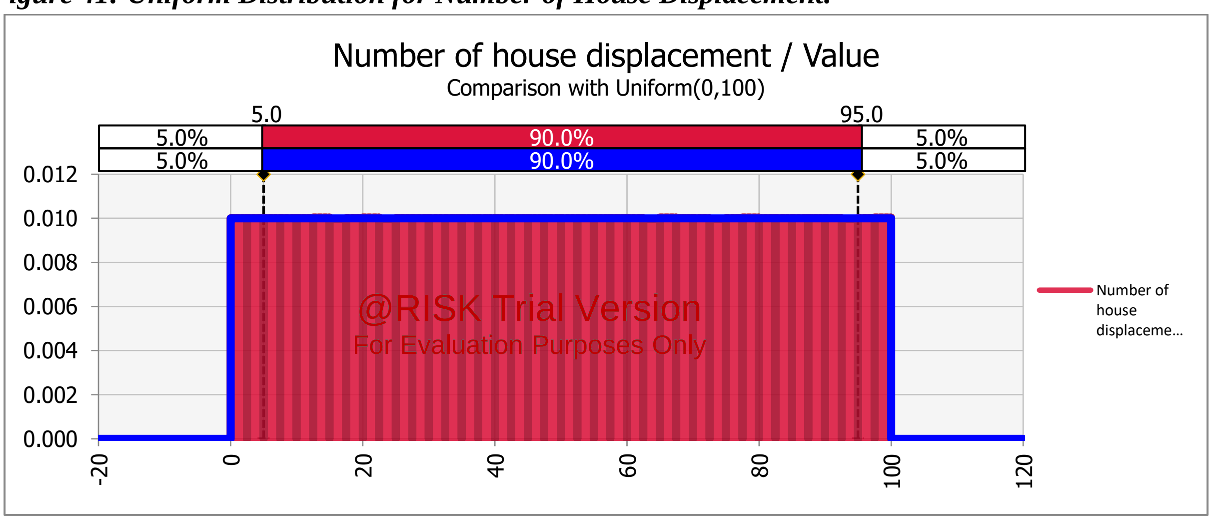


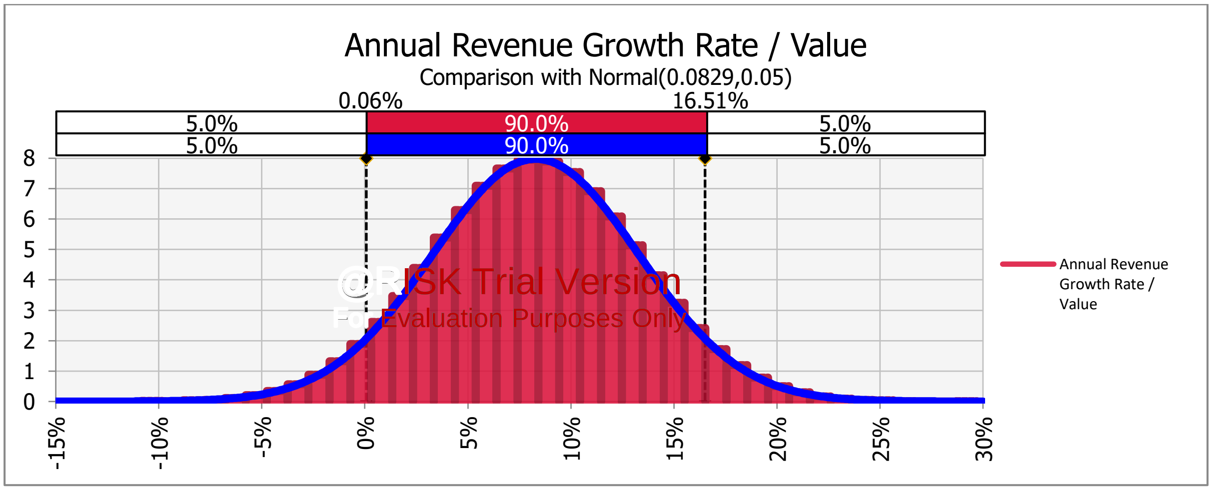
Figure 41: Uniform Distribution for Number of House Displacement:



For both of the economic parameters, the probability of all outcomes are same. Whatever discount rate we select the probability of all selection would be similar. Every outcome is equally likely to occur. In discount rate, every outcome in a uniform distribution occurs with the same relative frequency, the resulting shape of the distribution is that of a rectangle. Probabilities can be derived by area under the curve. Discount rate, uncertainty range is determined from 1.5 to 4.5. The probability that the discount rate lies between 2 to 4 is 90%. Due to construction of weir structures, some household is displaced. The displacement cost should also be including in project assessment. The uncertainty range for house displacement is generated from 0 to 100.

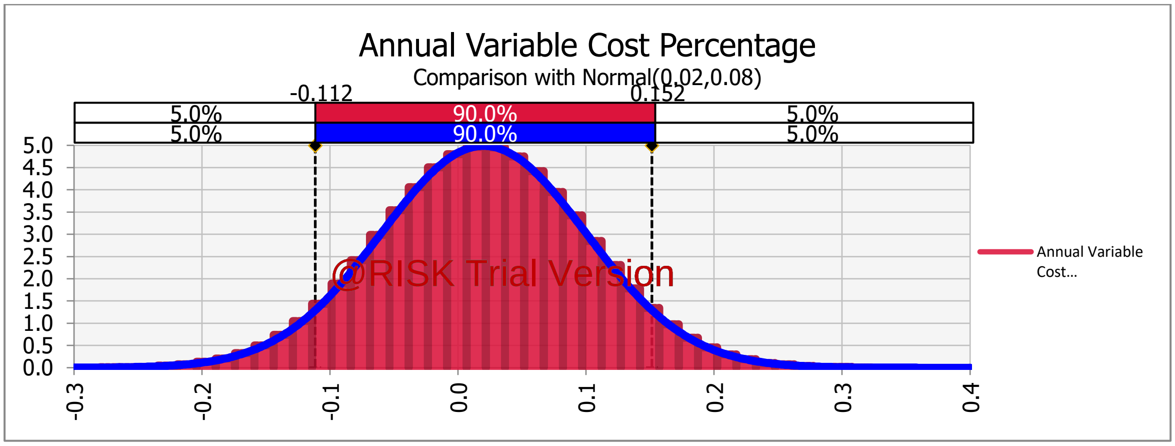
5.19 Results of Normal Distribution:

Figure 42: Normal Distribution of Annual Revenue Growth Rate:



In a normal distribution the parameters are the mean and standard deviation. The mean is the average and most likely value which is 0.0829. The probability of getting a positive revenue growth rate (or close to 8%) is 90%. There is only a 5% chance that the revenue growth rate would be lies between 0 to -5%. The value of standard deviation is 0.05 which shows the variability around the mean (0.0829). The distribution of this graph is symmetric meaning the value above the mean are just as likely as the value below the mean.

Figure 43: Normal Distribution of Annual Variable Cost Percentage:

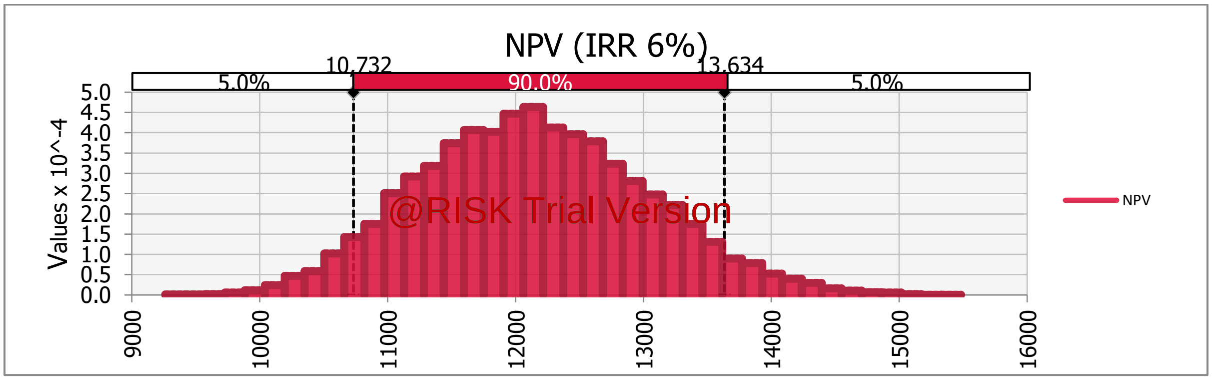


The variable cost ratio of a projects is calculated as variable costs divided by total revenues. It compares costs that change with levels of production to the amount of revenues generated by production. In such project fixed cost would be higher which is the one time cost and the annual variable cost would be lower which only include the maintenance cost. The revenue generated from such project is much higher. When the value in denominator is higher the overall effect on variable cost ration will become lower. In this figure, the mean value is 0.02. The probability of getting a positive variable cost ratio (or close to 2%) is 60%. There is 60% chance that annually the variable cost ratio would be positive. There is 30% chance that the variable cost ratio would be lies between 0 to -0.2%. The value of standard deviation is 0.08 which shows the variability around the mean (0.02). The distribution of this graph is symmetric meaning the value above the mean are just as likely as the value below the mean.

5.20 Monte Carlo Simulation Results:

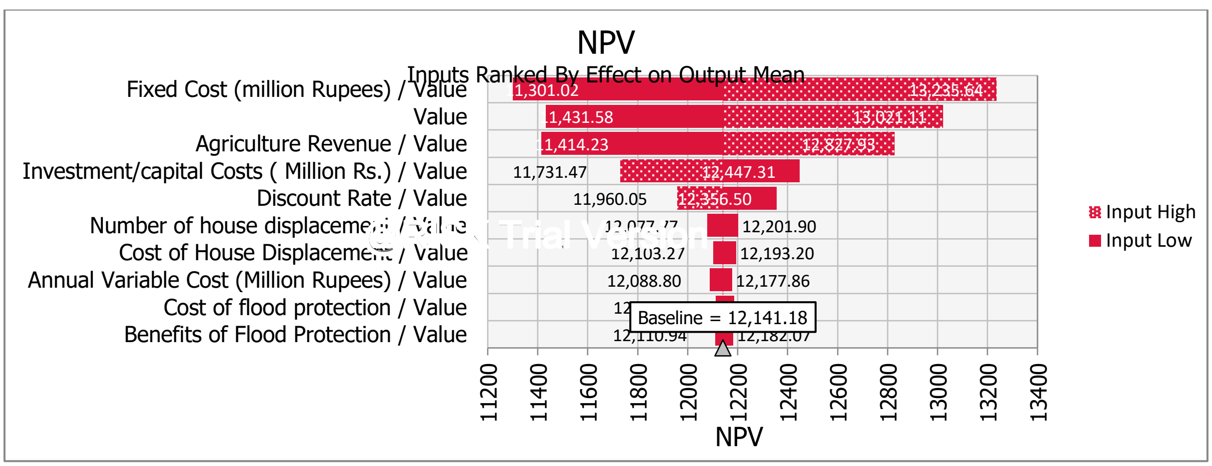
When the simulation runs @Risk keep tracking all 1000 values in the input cells (uncertain economic parameters) and the output cells (NPV). And it allow us to see these in a variety of ways. We analyze the chart of NPV by default of histogram because it let us to analyze the NPV in a number of way.

Figure 44: Monte Carlo Results of RCP 4.5 at discount rate of 6% with Complete Available water utilization:



This figure shows that the probability of NPV to lies within the range of 10000Million PKR to 13000Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. This positive NPV would only possible when the utilization of R4 runoff will be 100%. If we move towards the D, D2 water withdrawals situation the NPV value would be greatly reduced. The reason of this will be explained through the tornado charts.

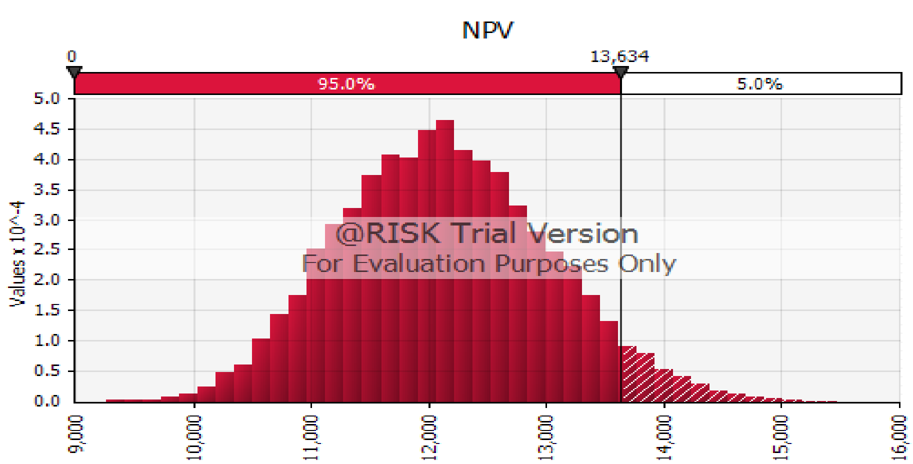
Figure 45: Tornado charts of Monte Carlo Results of RCP 4.5 at discount rate of 6% with Complete Available water utilization:



Here is the charts for the change in output mean options. Each bar indicates how much the mean NPV changes as a particular input varies over its range. Clearly the fixed cost has by far the greatest effect. As it varies over its range and the other inputs remain at their static values the mean NPV varies for about negative 11,301 Million PKR to about positive 13,235 Million PKR. As shown in tornado charts results, the agriculture revenue generated from the available runoff at climatic scenario 4.5 is fully utilized so the benefit of agriculture is higher. Because of these higher benefits the NPV will be higher because it is the 3rd highest contributing factor in simulating the NPV. A smaller change in water withdrawal will change the NPV within the specified ranges. However a large amount of uncertainty can move NPV towards the negative side.

On first figure of simulation it just giving the probability of the range 10732-13634 Million PKR. We can move these two slider on the chart to see the different probabilities and percentiles of this distribution. For example, to get the probability of a negative NPV we enter zero on the left slider.

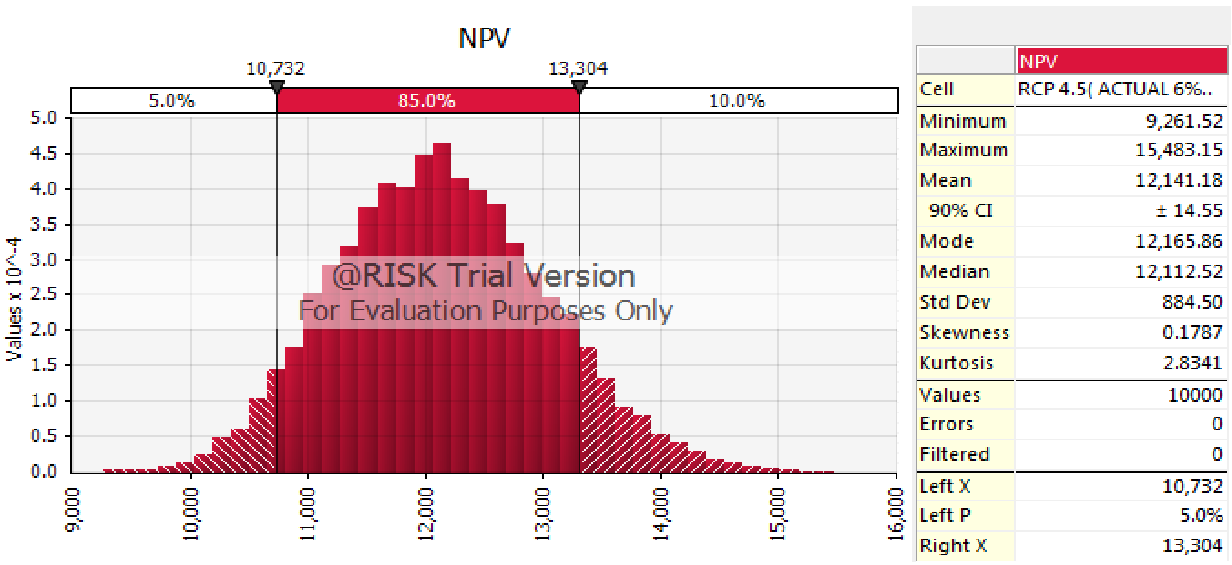
Figure 46: Probability of Net Present value equals zero:



	NPV
Cell	RCP 4.5(ACTUAL 6%..
Minimum	9,261.52
Maximum	15,483.15
Mean	12,141.18
90% CI	± 14.55
Mode	12,165.86
Median	12,112.52
Std Dev	884.50
Skewness	0.1787
Kurtosis	2.8341
Values	10000
Errors	0
Filtered	0
Left X	0
Left P	0.0%
Right X	13,634

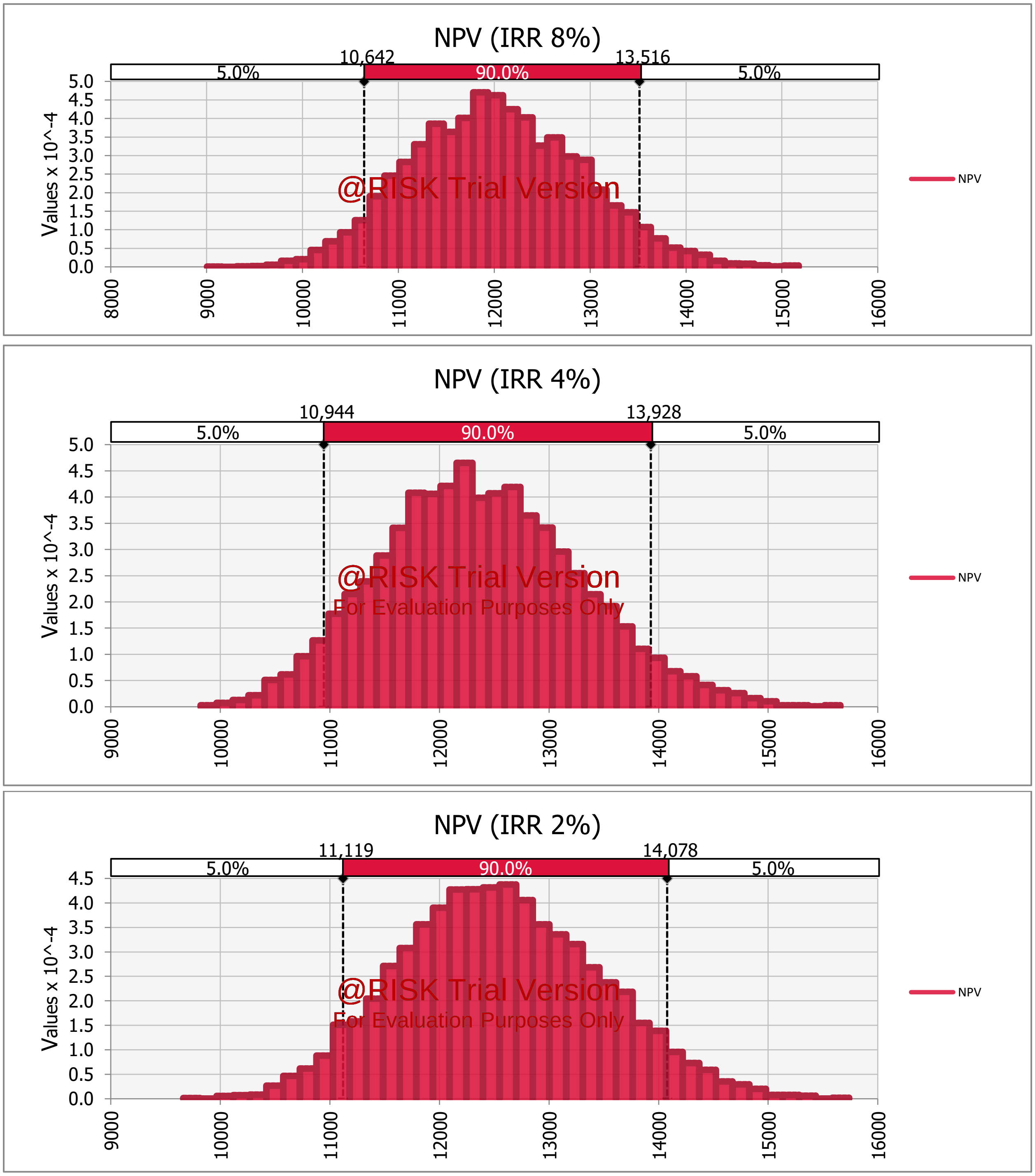
As we see this probability is close to zero percent. If planner is expecting that in future, climate change affect the runoff negatively/ reduced as compared to historical condition we can still get into this investment. Because it generate positive NPV outcomes. However it is based on the assumption that we will completely utilize the available water flow. We will analyze this as well in later sections that how variation in withdrawals can affect the NPV. In RCP 4.5, with complete utilization of water in agriculture the project pass the cost-benefit test with the NPV likely to be realized within the range of 10732-13634 Million PKR. The median NPV which is the 50th percentile is 12,112 Million PKR.

Alternatively to get the 90th percentile we can enter 10 on the above right slider;



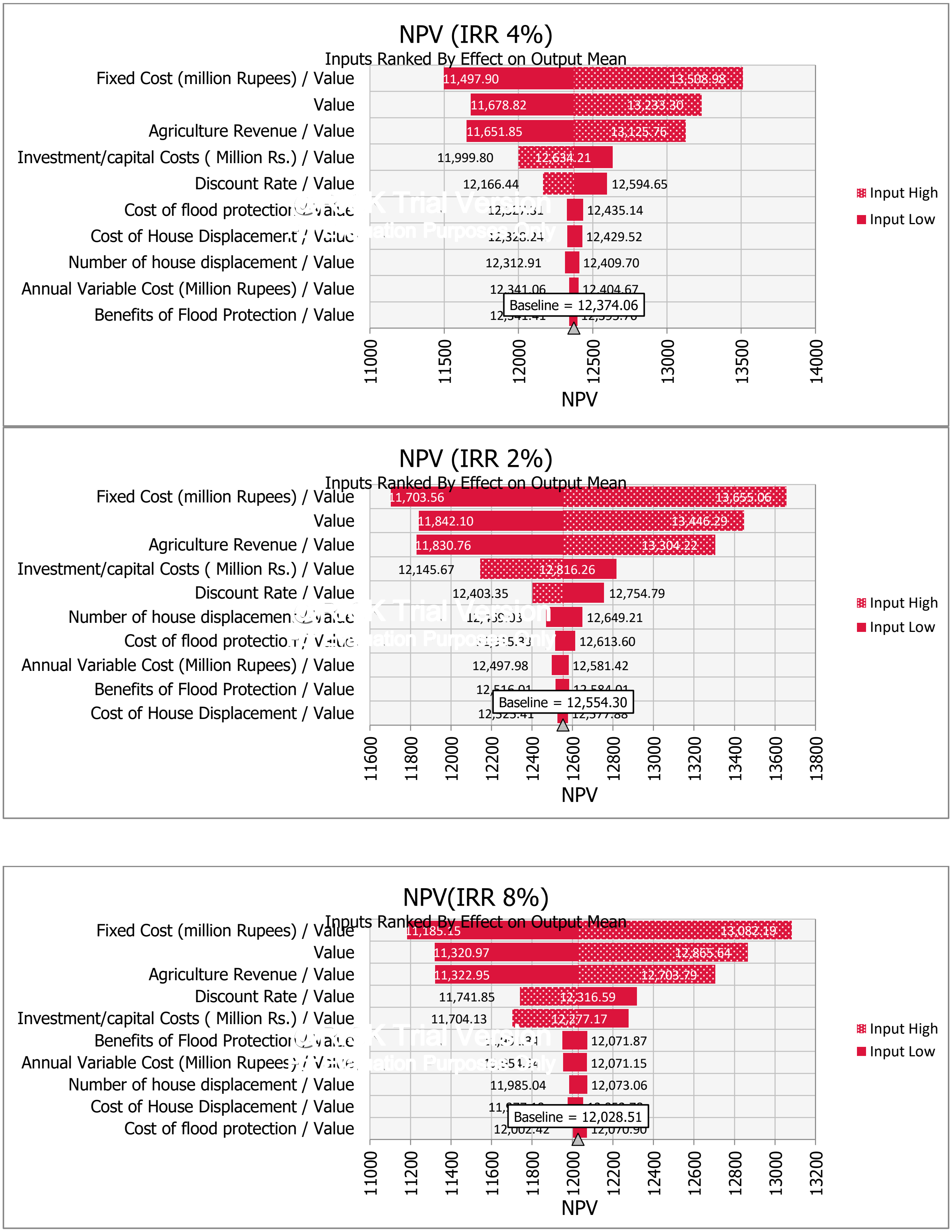
The result is close to 13,304 Million PKR. There is only 10% chance to having a NPV>13,304. A project rs might look at such probabilities and percentiles to make a go or no go decisions.

Figure 47: Monte Carlo Results of RCP 4.5 at discount rate of 4, 2 & 8% with Complete Available water utilization:



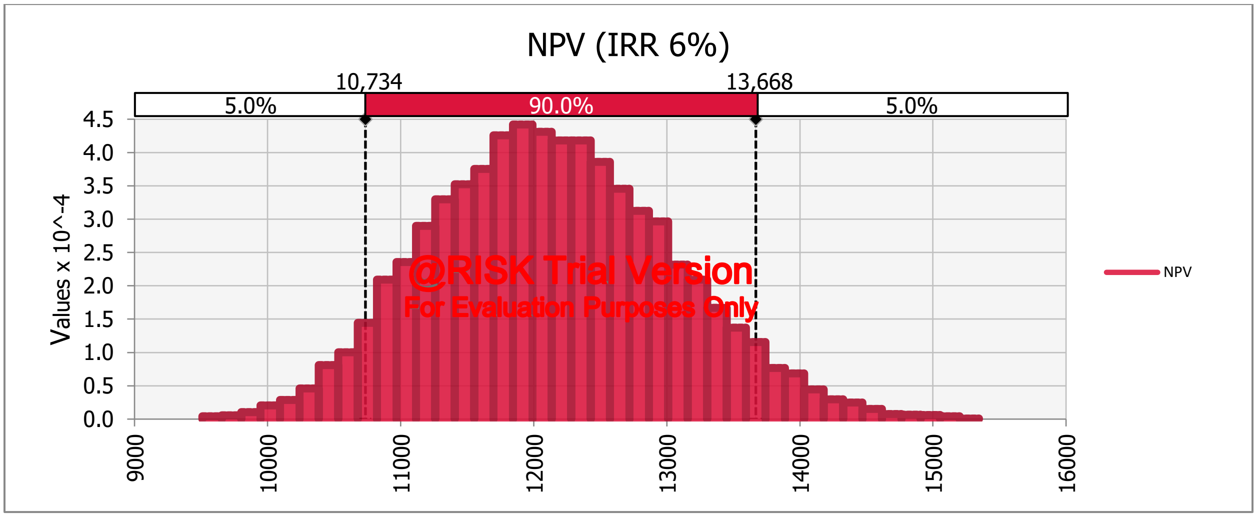
These figures shows the NPV values under different discount rate and their probability ranges. In case of discount rate of 8% the NPV value would be 11,226 Million PKR. Figure 1, shows that the probability of NPV to lies within the range of 10,642 Million PKR to 13,516 Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. In case of discount rate of 4% the NPV value would be 11,658 Million PKR. In figure 2, the probability of NPV is given which indicates that NPV lies within the range of 10,944 Million PKR to 13,928 Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. In case of discount rate of 2% the NPV value would be 11,887 Million PKR. Figure 3 shows the probability of NPV distribution with discount rate of 2%. The probability of NPV lies within the range of 11,119 Million PKR to 14,078 Million PKR would be 90% parameters and their uncertainty ranges. These positive NPV outcomes will only be realized when the utilization of R4 runoff will be 100%. One important thing that we noted here is, the results are as expected "when discount rate is lower the NPV value would be higher". This indirect relationship is fulfilled in our case. The NPV value would be higher when we choose the lowest possible discount rate which is 2%. However the NPV value not only sensitive to the selection of discount rate but it also depends on some hydrological and economic parameters but the effect of discount rate is also higher. Effects would be better shown through the tornado charts.

Figure 48: Tornado Charts of Monte Carlo Results of RCP 4.5 at discount rate of 6% with Complete Available water utilization:



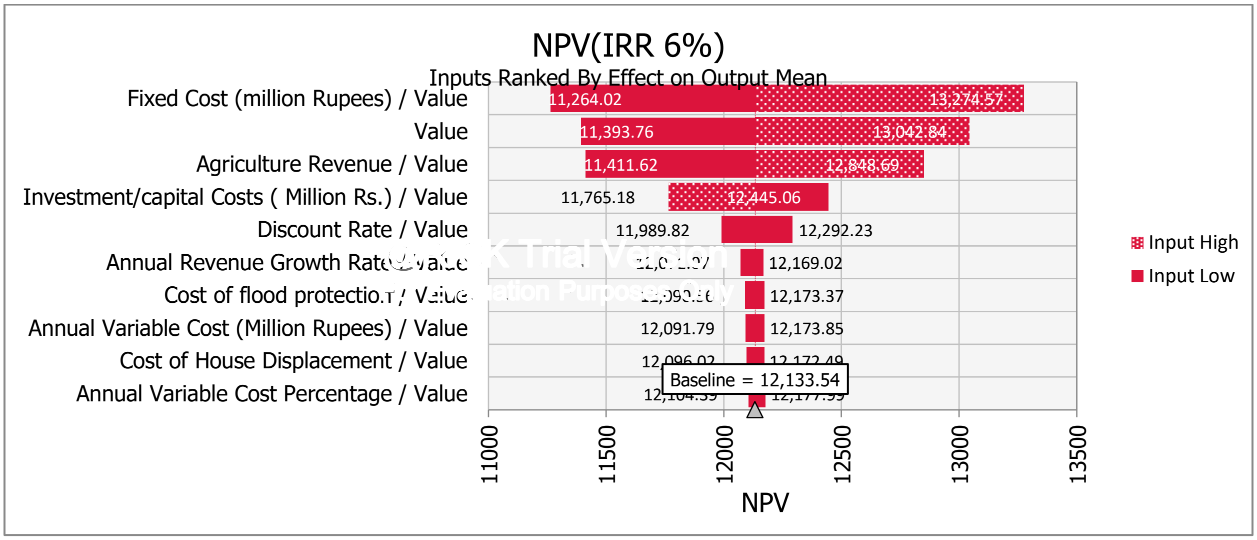
Here is the charts for the change in output mean options. Each bar indicates how much the mean NPV changes as a particular input varies over its range. Clearly the fixed cost and O&M costs has by far the greatest effect. As fixed cost varies over its range and the other inputs remain at their static values the mean NPV varies for about negative 11,000 Million PKR to about positive 14,000 Million PKR (a small variation in this range occurred because of changing in one factor which is discount rate). As shown in tornado charts results, the agriculture revenue generated from the available runoff at climatic scenario 4.5 is fully utilized so the benefit of agriculture is higher. Because of these higher benefits the NPV will be higher because it is the 3rd highest contributing factor in simulating the NPV in all three different discount rate. A smaller change in water withdrawal will change the NPV within the specified ranges. However a large amount of uncertainty can move NPV towards the negative side. In above mention all three cases the possibility of negative NPV would be zero. If planner is expecting that in future, climate change affect the runoff negatively/ reduced as compared to historical condition we can still get into this investment. Because it generate positive NPV outcomes in each of the selected discount rate however the NPV would be higher with a 2% discount rate. All these results would base on one assumption about withdrawal condition. We will analyze this as well in later sections that how variation in withdrawals can affect the NPV. In RCP 4.5, under the selection of different discount rates with complete utilization of water in agriculture the project pass the cost-benefit test in each scenario with the NPV likely to be realized ~11000 (or more) Million PKR. The median NPV (under discount rate of 2%) which is the 50th percentile is 12,519 Million PKR; Median NPV under discount rate of 4% is 12,324 Million PKR and; Median NPV under discount rate of 8% is 11,997 Million PKR. In 90^{th} percentile, the result is ~13,743 Million PKR (at discount rate of 2%); ~13,563 Million PKR (at discount rate of 4%) and; ~ 13,118 Million PKR (at discount rate of 8%). There is only 10% chance to having a NPV>13,743 (at IRR 2%); NPV>13,563 (at IRR 4%); NPV>13118 (at IRR 8%). A project planners might look at such probabilities and percentiles to make a go or no go decisions.

Figure 49: Monte Carlo Results of RCP 8.5 at discount rate of 6% with Complete Available water utilization:



This figure shows that the probability of NPV to lies within the range of 10,734Million PKR to 13,668Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. This positive NPV would only possible when the utilization of R8 runoff will be 100%. If we move towards different water withdrawals condition the NPV value will change. The reason of this will be explained through the tornado charts.

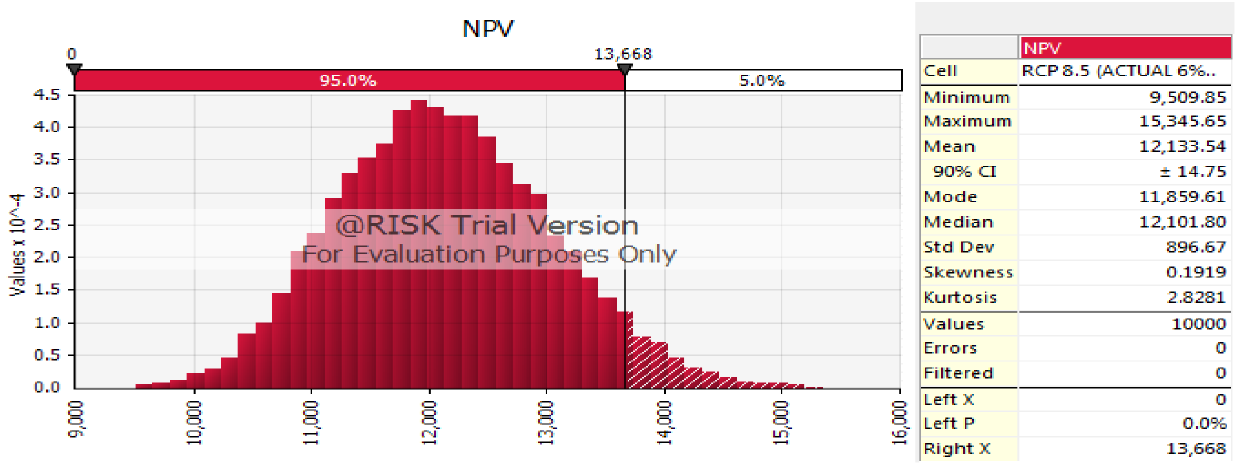
Figure 50: Tornado charts of Monte Carlo Results of RCP 8.5 at discount rate of 6% with Complete Available water utilization:



Here is the charts for the change in output mean options. Each bar indicates how much the mean NPV changes as a particular input varies over its range. Clearly the fixed cost has by far the greatest effect in both climatic scenarios. As it varies over its range and the other inputs remain at their static values the mean NPV varies for about negative 11,264 Million PKR to about positive 13,274 Million PKR. As shown in tornado charts results, the agriculture revenue generated from the available runoff at climatic scenario 8.5 is fully utilized so the benefit of agriculture is higher (but benefit would be lower as compare to R4 because river runoff is higher in R4). Because of these higher benefits the NPV will be higher because it is the 3rd highest contributing factor in simulating the NPV. A smaller change in water withdrawal will change the NPV within the specified ranges. However a large amount of uncertainty can move NPV towards the negative side.

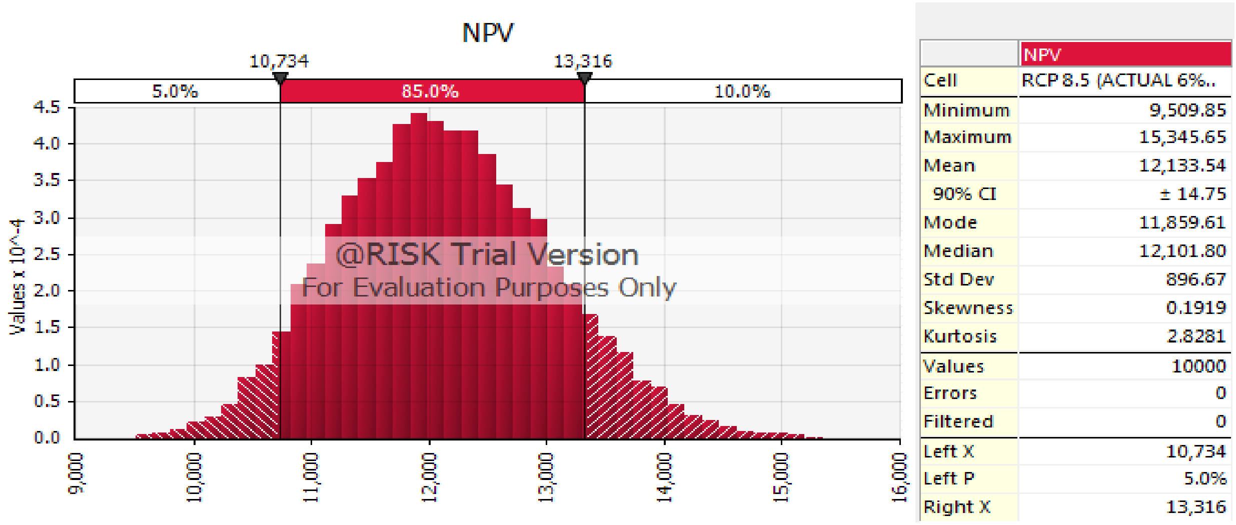
On first figure of simulation it just giving the probability of the range 10734-13668 Million PKR. We can move these two slider on the chart to see the different probabilities and percentiles of this distribution. For example, to get the probability of a negative NPV we enter zero on the left slider.

Figure 51: Probability of NPV equals zero in RCP 8.5



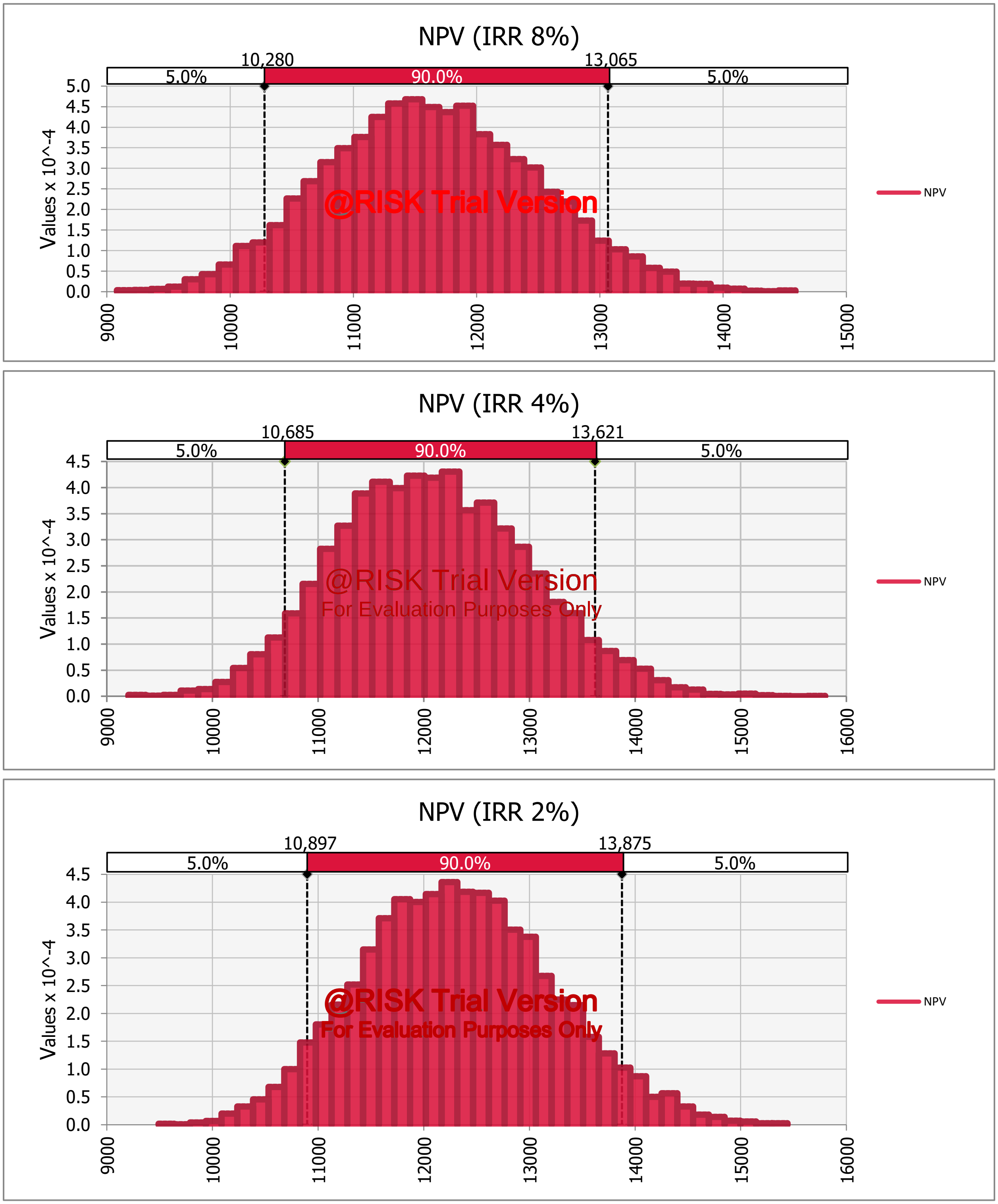
As we see this probability is close to zero percent. If planner is expecting that in future, climate change affect the runoff negatively/ reduced as compared to historical condition we can still get into this investment. Because it generate positive NPV outcomes. However it is based on the assumption that we will completely utilize the available water flow. We will analyze this as well in later sections that how variation in withdrawals can affect the NPV. In RCP 8.5, with complete utilization of water in agriculture the project pass the cost-benefit test with the NPV likely to be realized within the range of 10734-13668 Million PKR. The median NPV which is the 50th percentile is 12,106 Million PKR.

Alternatively to get the 90th percentile we can enter 10 on the above right slider;



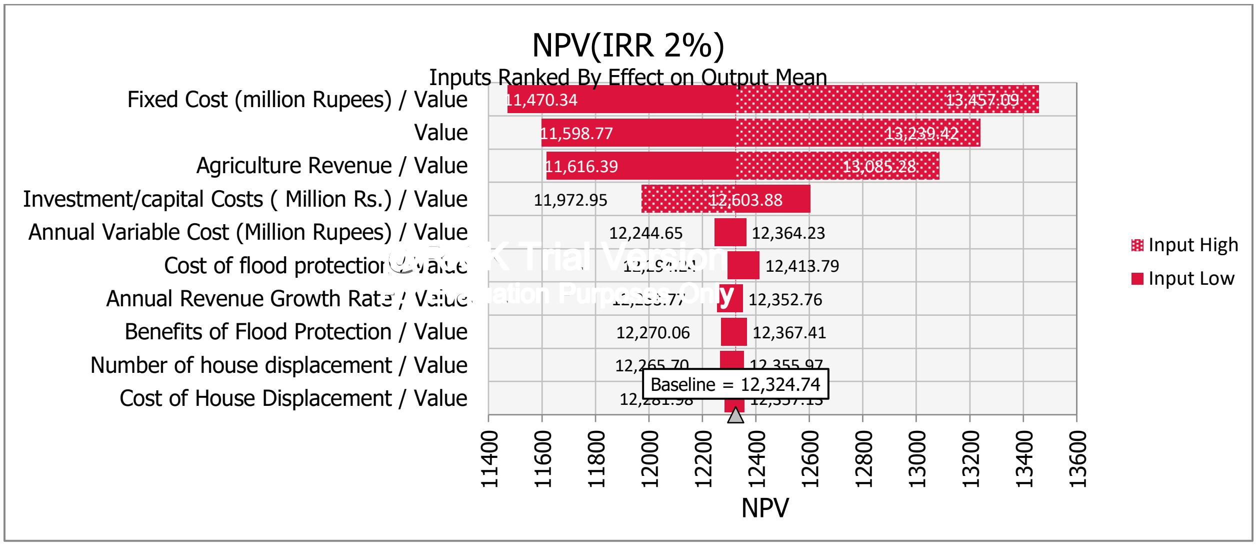
The result is close to 13,316 Million PKR. There is only 10% chance to having a NPV>13,316. A project planners might look at such probabilities and percentiles to make a go or no go decisions.

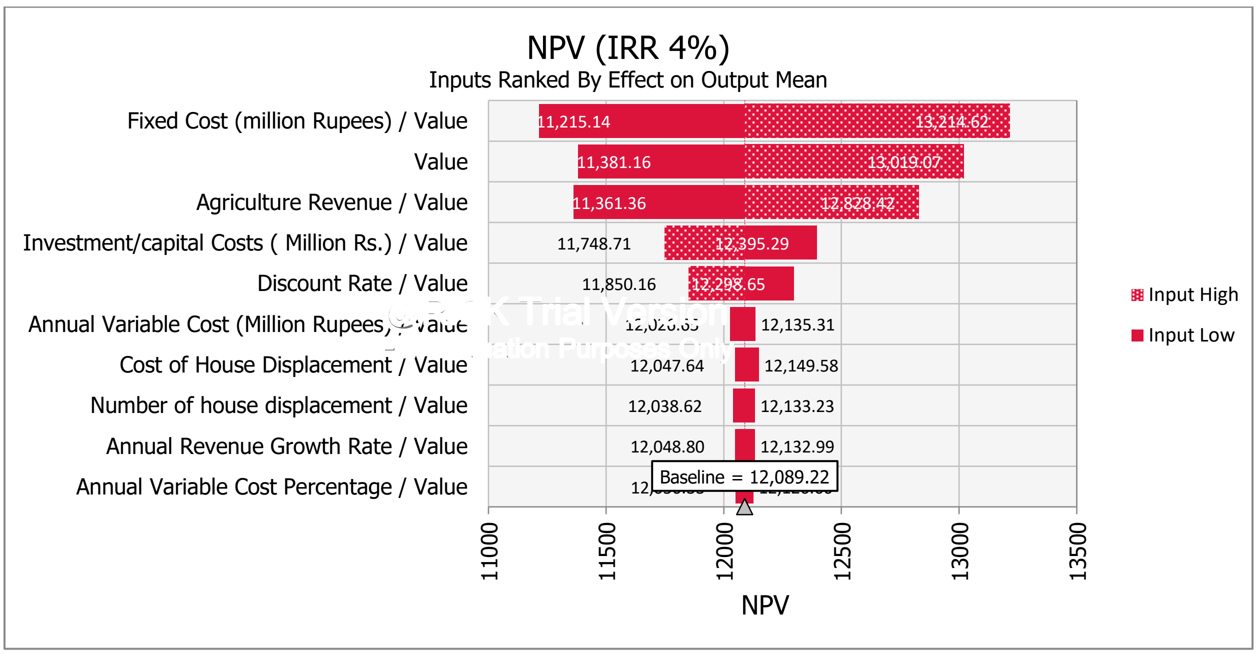
Figure 52: Monte Carlo Results of RCP 8.5 at discount rate of 4, 2 & 8% with Complete Available water utilization:

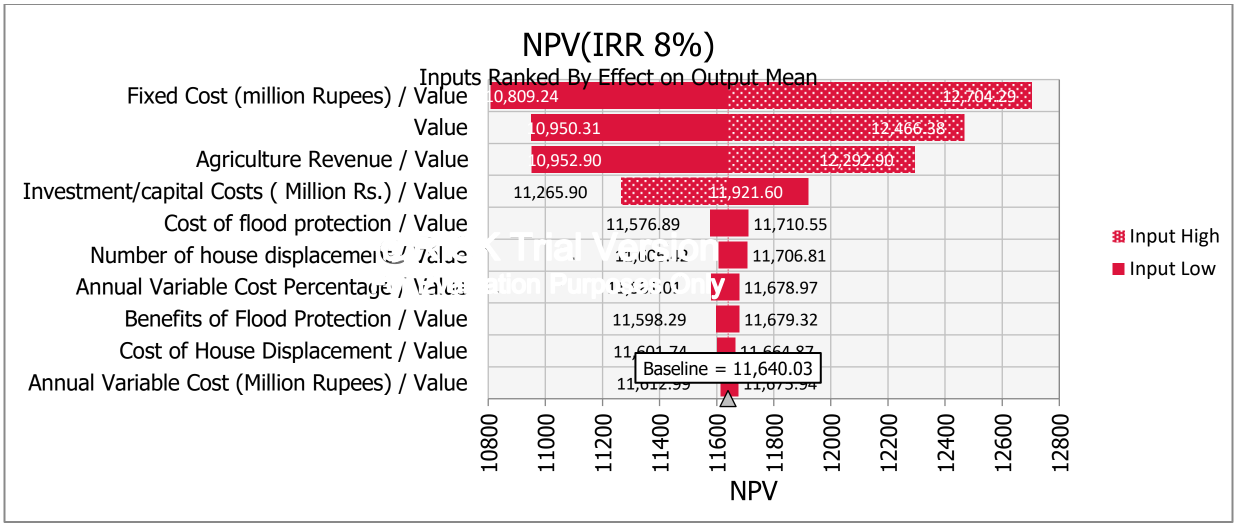


These figures shows the NPV values under climatic scenario 4.5 with different discount rate and their probability ranges. In case of discount rate of 8% the NPV value would be 10,951 Million PKR. Figure 1, shows that the probability of NPV to lies within the range of 10,280 Million PKR to 13,065 Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. In case of discount rate of 4% the NPV value would be 11,372 Million PKR. In figure 2, the probability of NPV is given which indicates that NPV lies within the range of 10,685 Million PKR to 13,621 Million PKR would be 90% by analyzing all the uncertain economic and hydrological parameters and their uncertainty ranges taken into account. In case of discount rate of 2% the NPV value would be 11,595 Million PKR. Figure 3 shows the probability of NPV distribution with discount rate of 2%. The probability of NPV lies within the range of 10,897 Million PKR to 13,875 Million PKR would be 90% parameters and their uncertainty ranges. These positive NPV outcomes will only be realized when the utilization of R4 runoff will be 100%. One important thing that we noted here is, the results are as expected "when discount rate is lower the NPV value would be higher". This indirect relationship is fulfilled in our case. The NPV value would be higher when we choose the lowest possible discount rate which is 2%. However the NPV value not only sensitive to the selection of discount rate but it also depends on some hydrological and economic parameters but the effect of discount rate is also higher. Effects would be better shown through the tornado charts.

Figure 53: Tornado charts of Monte Carlo Results of RCP 8.5 at discount rate of 4, 2 & 8% with Complete Available water utilization







Here is the charts for the change in output mean options. Each bar indicates how much the mean NPV changes as a particular input varies over its range. Clearly the fixed cost and O&M costs has by far the greatest effect. As fixed cost varies over its range and the other inputs remain at their static values the mean NPV varies for about negative 11,470 Million PKR to about positive 13657 Million PKR (at discount rate of 2%); 11,215 Million PKR to about positive 13,266 Million PKR (at discount rate of 4%); 10,809 Million PKR to about positive 11,708 Million PKR (at discount rate of 8%). As shown in tornado charts results, the agriculture revenue generated from the available runoff at climatic scenario 8.5 is fully utilized so the benefit of agriculture is higher. Because of these higher benefits the NPV will be higher because it is the 3rd highest contributing factor in simulating the NPV in all three different discount rate. A smaller change in water withdrawal will change the NPV within the specified ranges. However a large amount of uncertainty can move NPV towards the negative side. In above mention all three cases the possibility of negative NPV would be zero. If planner is expecting that in future, climate change affect the runoff negatively/ reduced as compared to historical condition we can still get into this investment. Because it generate positive NPV outcomes in each of the selected discount rate however the NPV would be higher with a 2% discount rate. All these results would base on one assumption about withdrawal condition. We will analyze this as well in later sections that how variation in withdrawals can affect the NPV. In RCP 8.5, under the selection of different discount rates with complete utilization of water in agriculture the project pass the cost-benefit test in each scenario with the NPV likely to be realized ~10,900 (or more) Million PKR. The median NPV (under discount rate of 2%) which is the 50th percentile is 12,296 Million PKR; Median NPV under discount rate of 4% is 12,057 Million PKR and; Median NPV under discount rate of 8% is 11,609 Million PKR. In 90^{th} percentile, the result is ~13,511 Million PKR (at discount rate of 2%); ~13,281 Million PKR (at discount rate of 4%) and; ~ 12,746 Million PKR (at discount rate of 8%). There is only 10% chance to having a NPV>13,511 (at IRR 2%); NPV>13,281 (at IRR 4%); NPV>12,746 (at IRR 8%). A project planners might look at such probabilities and percentiles to make a go or no go decisions.

5.20.1 Comparison between R4 & R5 Economic Outcomes:

In RCP 4.5 the NPV outcomes will be higher in each discount rate as compare to RCP 8.5. The only factor that is difference between these scenarios is the hydrological variability (as shown in section). The economic uncertain parameters are same for both climatic scenarios. In R4 scenario, the river flow is higher (as compare to R8) because this scenario reflect the moderate emission and its effect on precipitation is higher which in return reduce the river flow as compare to historical condition (almost 50% reduction is projected). However, R8 reflects the high emission scenario, which results in low river flow. Lower inflow result in lower agriculture benefits. That's why the variation in NPV will be shown in different climatic scenarios.

Table 5.16: Comparison of Net Present Value outcomes in climatic scenarios:

Discount Rate	RCP 4.5	RCP 8.5
2	11887	11595
4	11658	11372

6	11438	11158
8	11226	10951

Summary:

This chapter demonstrated a simple application of the simulation-based, integrated hydro economic framework developed in this research. The reader will recall that development of this framework was inspired by the difficulty associated with using conventional hydrological planning tools when future climatic, hydrological and economic conditions are highly uncertain. The application discussed here explored how the economics of the Nari River structures could be affected by climate change. We explored the impact of adding various climate-hydrological and climate-economy linkages to the model, as well as the importance of various uncertainties related to the economic performance of this project. The analysis showed that the economic performance of this infrastructure could very well improve relative to the historical situation if the projections obtained from a Representative Concentration pathways for the R4 and R8 scenario are borne out. Such improved outcomes would suggest that a weir structure at Nari River may provide considerable adaptation benefits to the Nari River riparians.

These results are, however, sensitive to several important uncertainties. As is common in the assessment of capital-intensive investments with long economic lives, varying the social rate of discount has a very large effect on project outcomes. Under R4 and R8-scenario conditions, it was also found that uncertainty associated with plausible ranges of future inflow changes could play an important role in shifting NPV outcomes. Other parameters of importance in changing the calculation of net benefits were related to the agriculture production generated at Nari River and fixed cost of project, O&M costs, the length of the planning horizon, the natural hydrological variability in the Nari River and the extent of irrigation development in the basin.

To investigate the effects of uncertainty in parameter values, we turn to NPV distributions obtained from the Monte Carlo model of the simulation framework. Consistent with the results summarized above, we see that decreased inflows and the physical linkages tend to shift the cumulative distribution of NPV outcomes to the left. Monte Carlo simulation result shows the project pass the cost benefit test in all climatic condition but following one assumption that the water is completely utilized. Under different discount rate NPV is positive and probability of negative NPV is zero in all situation. When discount rate increases the value of weir structure decrease.

Table 5.17: Net Present Value Calculation under Different Discount Rate and Different Climatic Scenarios (with complete Utilization of flow)

Discount Rate	RCP 4.5	RCP 8.5	Historical Climate
2	11887	11595	24142
4	11658	11372	23678
6	11438	11158	23231
8	11226	10951	22801

CHAPTER 6: CONCLUSION AND POLICY RECOMMENDATIONS

Summary of Key Findings

Based on the results of the study, the conclusion can be summarized as following:

It was found that Nari River is sensitive to climatic variability, as it is influenced by the variability in temperature trends and changing monsoon pattern. And the results of the study also found that the official analysis and valuation conducted for the project appraisal did not included such sensitive and key parameters which does have impact on the water availability in the future, and those parameters if neglected, project may be questionable as far as climate impact assessment is concerned. The current irrigation demand cannot be fulfilled according to the constructed climate projection scenarios (RCP 4.5 and RCP 8.5), even if the reduction of 50% is imposed on RCP 4.5 scenario. Water balance was also found to be negative in the historical perspective as irrigated area is developed with respect to time.

The net present value (NPV) of the six flood dispersal project was also found to be sensitive to irrigation extent, as full utilization scenario was set for agriculture use. As irrigation increases, NPV value becomes greater. If the complete utilization of water for irrigation is set, project pass the cost-benefit test under every discount rate used in the analysis i-e, 2, 4, 6, 8.

The net present value (NPV) of the project is even more sensitive to climatic variation, as in climate projection scenario 4.5, the benefits of the projects are less than the historical climatic scenario and benefits are even further decreased in the projection scenario RCP 8.5. although project pass the cost-benefit test keeping an assumption that full utilization of water is set to irrigation purpose.

It was also found that the main reason of passing of NPV test was that the project is a one-time investment and the benefits are set to agriculture production which give fair returns every year. Although in real world scenario, full utilization is difficult to achieve if lessens are to be learnt from past 30-year data. Full utilization can be achieved through determination of land area cultivated, water resistant cropping, and integrated utilization strategies to be opted before project implementation.

Policy Recommendations

- Important recommendation coming out from the study results is that climate impact assessment should a part of every project dealing with natural resources. As natural resources like water are being affected due to some climatic factors mainly: temperature and precipitation.

- Rather than using fixed economic parameters in the analysis, it should vary according to the uncertainty ranges.

- Carbon (CO_2) emissions analysis due to project should be the part of evaluation. Also the cost incurred on per unit of CO_2 emission should be calculated and analyzed accordingly.

- Project appraisal should be tested according to different social discount rates, as such projects aim to provide maximum social inter-generational benefits which can be achieved only by putting lower value of discount rate. The discount rates used in the appraisal of six flood dispersal structure project are much higher than it should be in order to provide inter-generational social benefits

- Compensation should be provided to the society and households who were disturbed and migrated in the implementation stage of the project. Land displacement costs should also be included in the analysis. As these costs and losses are the core part of environmental impact assessment. The official project appraisal did not include such costs and compensations.

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