DAVIS OGILVIE & PARTNERS LIMITED
Level 1, 24 Moorhouse Avenue, Addington
PO Box 589, Christchurch 8140
0800 999 333 / 03 366 1653 / hello@do.nz
Offices in Christchurch, Timaru, Nelson & Greymouth. **www.do.nz**

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MEMORANDUM

Project:	Manuherekia Catchment Hydrology	**Author:**	Ian Lloyd
Job No.:	40102.	**Date:**	Monday, 6 July 2020
Subject:	Manuherekia Catchment GoldSim model – scoping document – revised draft		
Issued to:	ORC and hydrology consultants		

1.0 INTRODUCTION

As per the Manuherekia[1] Catchment Hydrology – Scope of Work V6 there is need to develop a hydrology model of the Manuherekia Catchment using the GoldSim modelling platform. The first step in developing the model is the preparation of this model scoping document. This memorandum briefly documents the following:

- The objective and scope of the proposed Manuherekia Catchment GoldSim model.
- The model logic and includes a model logic diagram.
- The extent, complexity and functionality of the model including key model assumptions.
- The model output – what and where.
- The key model input data sets, how they will be developed and any key assumptions.

The timeframe for model development is extremely tight. To achieve the timeframe there is need for various activities to be undertaken in parallel and by a number of organisations. This document aims to guide the various work programmes, to ensure consistency and to inform stakeholders and future users of the model, of what the model will and will not do.

This document was initially prepared in draft to allow contributors, stakeholders and future model users to comment and therefore reduce the potential for future model changes or updates. Comments were received from the Otago Regional Council (ORC) in regard to future minimum flow sites and model functionality. This revised draft document includes additional comments relating to the minimum flow sites and model functionality and will be circulated to ORC for final comment prior to being finalised. Once finalised this document will direct model development.

[1] Manuher<u>e</u>kia rather than Manuher<u>i</u>kia is used throughout this document other than for named flow recorder sites, as it is understood to be the spelling and annunciation preferred by ORC.

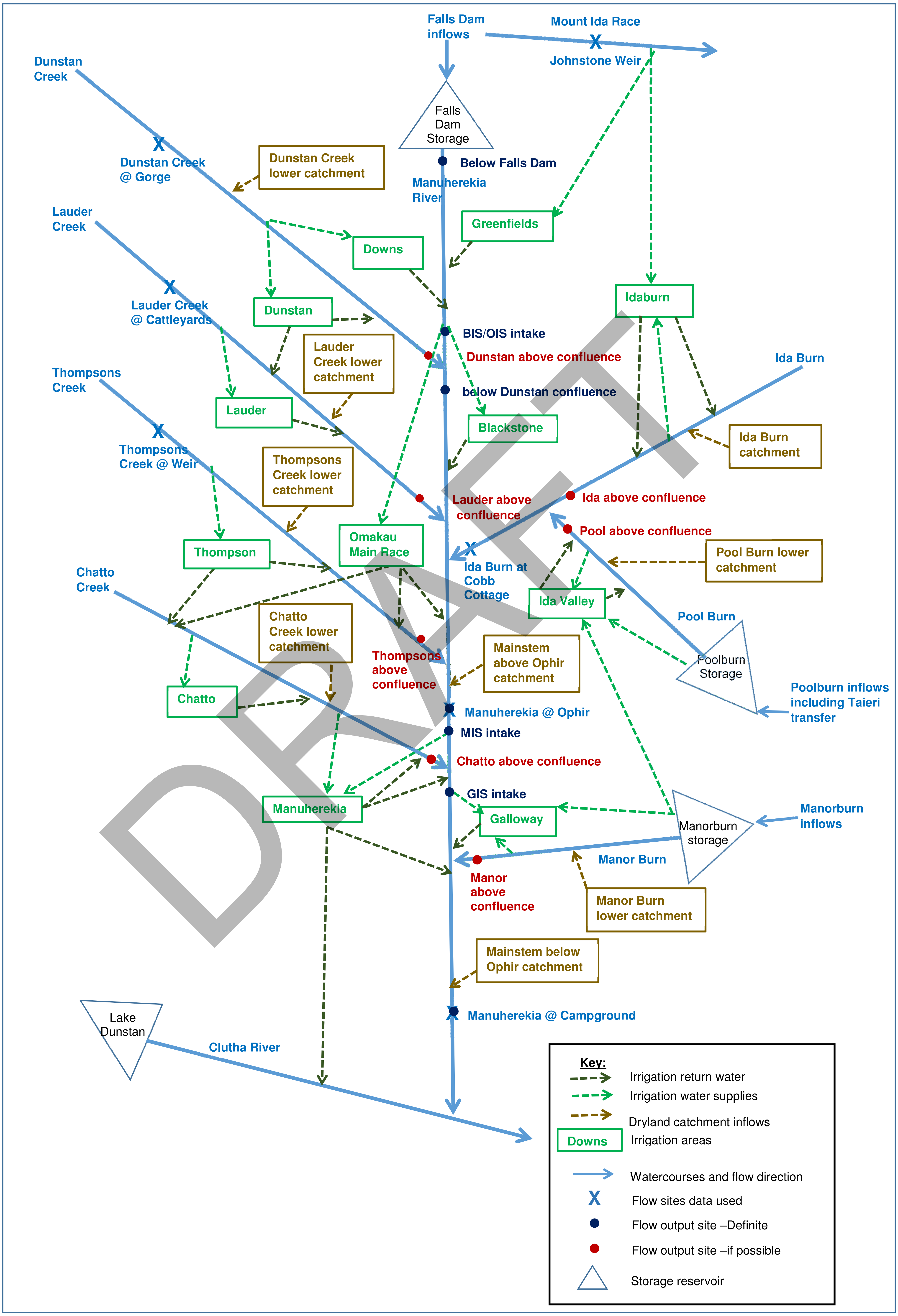
2.0 MODEL OBJECTIVE AND SCOPE

The objective and scope of the Manuherekia Catchment GoldSim model is to provide ORC and the various stakeholders with a hydrological model which can be used by all parties to assess water management scenarios and which supports the upcoming planning, consenting and water management processes throughout the Manuherekia catchment.

3.0 MODEL LOGIC DIAGRAM

The model will be based on the following model logic diagram which highlights the water infrastructure that will be included and the key model nodes.

Figure 1: Manuherekia Catchment GoldSim Model – Model Logic Diagram



T:\projects\40s\40102 - Manuherekia Hydrology\Civil\hydrology model\model logic and background\Model logic diagram ORC.docx

4.0 MODEL EXTENT, COMPLEXITY & FUNCTIONALITY & KEY MODEL ASSUMPTIONS

The Manuherekia Catchment GoldSim model shall cover the entire Manuherekia catchment and include any significant water imports from, and exports to, neighbouring catchments. The model is to be based on current hydrological understanding, shall focus on suitably representing current conditions and shall allow various potential future management scenarios to be rapidly assessed. While the model is to focus on the current water infrastructure (namely the existing main water storages, water races, sub-catchment water transfers and irrigated areas), and water management it needs to be flexible enough to allow future inclusion of additional infrastructure (i.e. water transfers, additional storage etc.) and management tools.

The model will use information and knowledge contained in the various previous hydrological models prepared for the catchment (principally the excel and GoldSim models prepared for MCWSG and MRL and NIWA's TopNet and CHES models prepared for ORC) and is expected to have a similar complexity as the existing models.

Standard model components will be developed for sub-catchments, irrigated areas, storage reservoirs, irrigation intakes, main stem node points and minimum flow locations. Each standard model component will include mass balance checks to confirm conservation of mass. Development of standard model components will facilitate the model build and will support future transferability to other catchments if required.

The standard sub-catchment model component will include the following components:

a) An upstream input flow node (for flow above any irrigation takes). For most sub-catchments an upstream flow record is available from either measured flow data or from the TopNet rainfall runoff model estimates.

b) A downstream flow node below all the irrigation takes and catchment inflows – this will be the principal flow output node for the sub-catchment. To limit the need for post processing of the outputs where possible standard hydrological statistics and plots for the downstream flow node will be developed within the model.

c) An irrigated area which will be attached to a water source and will typically take from immediately below the upstream input flow node. The irrigated area will have a water demand and a return water time series. Return water from the irrigated area will contribute flow to the downstream flow node. Water supply reliability will be calculated for the irrigated area on a volumetric basis i.e. volume supplied/volume demanded.

d) A dryland catchment representing the unirrigated area between the upstream and downstream flow nodes. This catchment will contribute flow to the downstream flow node.

The model will be based on a daily (midnight to midnight) time step and hydrological years (1 July to following 30 June). The intention is for the model to cover the period 1 July 1973 to 30 June 2019. All model inputs and outputs will be based on average daily values. The model will not consider travel times, and inflows entering the system on a particular time step will be assumed to exit the system on the same time step (other than in relation to water storage). The model shall maintain conservation of mass (water) on a daily basis.

The model will not include calibration factors rather it will focus on using known data (i.e. area irrigated, catchment size, measured flow, catchment yields etc.) to replicate the existing system as accurately as possible and then a model validation process will be undertaken. Validation of the model will be focused on comparing model predictions for: reservoir storage, water supply and river flows against measured storage i.e. reservoir water level (predominantly for Falls Dam), water meter take data (a small selected number of water meter records including both scheme and individual takes will be used to verify modelled water demand and water supply) and measured flow data at particularly the downstream flow sites of Ophir and Campground. Where possible, individual sub-catchments will be validated prior to the main stem. Main stem validation will be undertaken in an upper catchment to lower catchment direction i.e. Ophir first then Campground.

The model will focus on replicating the current situation and assessing the relative change associated with various proposed future management scenarios. The model is not designed to provide an estimate of natural flows in the lower parts of the catchment. The model will be most valuable in considering relative change between scenarios on a weekly, monthly and particularly seasonal basis. Some discrepancies between individual time steps are expected. There are significant sub-catchment differences in the amount and quality of hydrological data. Uncertainties will be highest for those catchments with limited data namely the Manor Burn, Pool Burn, Ida Burn and Chatto Creek.

A significant challenge in the existing models is how to deal with the lower valley parts of the catchment where there is significant water use (irrigation), reuse of water, water transfers and there have been significant land use and water use changes over time. The proposed model will be based on current (2019) land and water use and will use historic climate conditions to assess the effect of differing management scenarios on current conditions. Water demand will be modelled via standard soil moisture models for two irrigation types (spray and flood) and will be combined with estimated irrigated areas for each type. A small number of selected water meter records including both scheme and individual takes will be used to verify modelled water demand. The soil moisture models provide time series of soil moisture, water demand and drainage/runoff water. The drainage water will be assumed to return to the watercourse. The soil moisture models will also be run for dryland (no irrigation) conditions to estimate drainage/runoff from the dryland part of the lower catchment between the upstream and downstream flow nodes. This dryland drainage/runoff will be assumed to return to the watercourse at the downstream flow node. Neither delays in drainage/runoff nor storage within and discharge from groundwater systems will be considered.

Where necessary catchment, sub-catchment, irrigated and dryland areas will be delineated using GIS with irrigated areas checked against user records.

In terms of management options ORC and the Technical Advisory Group (TAG) have indicated they desire the model to have significant functionality. Including additional functionality complicates the model build but potentially makes scenario assessment simpler. Given the tight project timeframes, a balance is needed between including additional functionality in the model which will complicate/extend the model build and the effort require to run and asses various scenarios. Table 1 below summarises the desired functionality, the associated model build implications and the proposed solution/outcome. To ensure model functionality is well understood and suitable scenarios are development, the completed / verified model will be available for demonstration prior to scenario development.

A dashboard will be included in the GoldSim Model (similar to that in the current GoldSim Model) which will allow rapid alteration of key variables (namely minimum flows, irrigation demand, irrigated area, storage attributes and allocation priorities) and support scenario modelling.

<table>
<tr><th colspan="6">Table 1: Desired Model Functionality, Implications and Proposed Solutions/Outcomes</th></tr>
<tr><th colspan="3">Functionality desired by ORC and TAG</th><th rowspan="2">Model build implication</th><th colspan="2" rowspan="2">Proposed Solution / Outcome</th></tr>
<tr><th>Overview</th><th colspan="2">Details</th></tr>
<tr><td rowspan="13">Multiple minimum flow locations</td><td colspan="2">The following minimum flow sites desired</td><td rowspan="13">Minimum flow locations, particularly locations downstream of takes, require significant model build effort as loops are required to restrict upstream takes to achieve a desired downstream flow. Upstream minimum flow sites are considerably simpler. The current GoldSim Model has 6 minimum flow sites of which 4 are above the takes. Ten minimum flow sites are desired all of which other than Manuherikia Downstream of Falls Dam are downstream of significant takes.</td><td rowspan="2">Priority</td><td rowspan="13">The following main stem minimum flow sites will be included in the model:
• Manuherikia Downstream of Falls Dam
• Manuhereikia @ Ophir
• Manuherikia @ Campground
As the river is used to convey irrigation water the two upstream sites (below Falls and Ophir) only become important when Falls Dam is empty or during the non-irrigation season.

The model build process will commence with a standard sub-catchment. If a downstream minimum flow site can be simply incorporated then the same methodology will be applied to all sub-catchment. If a downstream minimum flow proves too difficult an upstream minimum will be applied to all sub-catchments with a downstream flow output node. Effort to include minimum flow sites will be based on the stated priority. The lower priority sites are unlikely to be included given the limited model build timeframe.</td></tr>
<tr><td>Location</td><td>Priority</td></tr>
<tr><td>Manuherikia Downstream of Falls Dam</td><td>A</td><td>1</td></tr>
<tr><td>Manuhereikia @ Ophir</td><td>A</td><td>3</td></tr>
<tr><td>Manuherikia @ Campground</td><td>A</td><td>2</td></tr>
<tr><td>Dunstan Creek @ Confluence</td><td>A</td><td>4</td></tr>
<tr><td>Lauder Creek @ Rail Trail</td><td>A</td><td>5</td></tr>
<tr><td>Pool Burn @ Cob Cottage</td><td>B</td><td>10</td></tr>
<tr><td>Ida Burn @ Auripo Rd</td><td>B</td><td>9</td></tr>
<tr><td>Pool Burn @ Auripo Rd</td><td>B</td><td>8</td></tr>
<tr><td>Thomson's Creek 2 SH</td><td>A</td><td>6</td></tr>
<tr><td>Chatto U/S Confluence</td><td>A</td><td>7</td></tr>
<tr><td>Manor Burn @ Confluence</td><td>B</td><td>8</td></tr>
<tr><td>Multiple min flow sites</td><td colspan="2">The ability to have takes linked to multiple minimum flow sites i.e. a tributary minimum and then a minimum at Campground.</td><td>Current GoldSim model links each take to one minimum flow site only. Linking to multiple minimum flow sites is expected to be difficult.</td><td colspan="2">Each take will be linked to one minimum flow site only. Initially this will focus on the closest most relevant site for that irrigated area typically a tributary take will be linked to the tributary minimum. Following the main model build the ability to link the sites to a different minimum flow site will be investigated and included if possible i.e. all takes linked to the Campground minimum flow site only.</td></tr>
<tr><td>Seasonal min. flows</td><td colspan="2">The ability to stipulate different conditions in the irrigation season than outside.</td><td>Is included in the current GoldSim model.</td><td colspan="2">The model will include the ability to set different minimum flows for the irrigation season than for the non-irrigation season. The model will allow the irrigation season to be specified.</td></tr>
<tr><td>Flow sharing</td><td colspan="2">The ability to have flow sharing above the minimum flows and potentially different sharing regimes for different allocation blocks.</td><td>The current GoldSim model does not include either flow sharing or allocation blocks and both will be difficult to include.</td><td colspan="2">The current flow regime and management practices in the catchment do not include flow sharing. We will attempt to include flow sharing in the initial standard sub-catchment model build. If it proves to be relatively simple we will include flow sharing in all sub-catchments, if it is difficult it will be ignored and only reconsidered after completion of the main model build as time allows.</td></tr>
<tr><td>Allocation Blocks</td><td colspan="2">The ability to have primary and secondary allocation blocks with different management regimes and potentially different uses i.e. take for irrigation rather than a take for storage.</td><td>The current GoldSim model includes current (Primary) and new future (Secondary) takes although both are for irrigation, have the same allocation priority and have the same management regimes. Including different regimes for the blocks is expected to be difficult.</td><td colspan="2">The model will only consider irrigation takes and will focus on direct run of river takes with only the 3 large scheme storages (Falls, Poolburn and Manorburn/Greensland) considered. Primary and Secondary allocation block linking back to irrigated areas will be included which will initially have the same management regimes. Potentially additional storage and differing management regimes could be added to feed the secondary irrigated area at a later date after initial model build if time allows.</td></tr>
</table>

Storage effect	The ability to differentiate storage effects on flow and supply reliability from run-of river effects i.e. “Natural water” versus “Stored water”	Current GoldSim model does this by comparing scenarios rather than direct calculation. The current model stores all dam inflow and then allocates the stored water to initially minimum flows and then takes.	This is considered an important issue which will be included in the model. Essentially it means including the situation where stored water is only used for irrigation and not used to support minimum flows. Note the ability to use stored water (in Falls Dam) to support minimum flows will be included in the model. .
Flushing flows	The ability to release flushing flows from Falls Dam.	The current GoldSim model does not include flushing flows but does include the outlets physical capacity.	The limited capacity (max outlet discharge ~4 m^3/s) of the current Falls Dam outlet limits the ability to release large flushing flows. Flushing flows from Falls Dam will be included in the model based on both the current outlet and a modified outlet.
Climate Change	The ability to assess the effects of climate change on flows, storage operation and supply reliability.	The current GoldSim model includes simple climate change scaling factors which related to irrigation demand and natural flows.	According to the current Manuherekia Catchment Hydrology Scope (V6) climate change is included in Phase 2 of the project and is yet to be fully scoped. Assessment on climate change is likely to involve a two stage process: 1. Assessing how climate change will affect the key model input series of natural inflows above the takes and irrigation demand. 2. Inputting climate adjusted time series into the model and assessing the implications on flows downstream of the take, storage operation and supply reliability. The above process is expected to be relatively complicated and time consuming. As an interim measure simple climate change scaling factors will be included in the model.

5.0 KEY MODEL OUTPUTS

The key model outputs are summarised in the table below:

Model component	Locations	Output (daily time series/plots of)	Comment
Reservoirs	Falls Dam, Poolburn Reservoir Manorburn/Greensland Reservoir	Live storage volume. Potential supply restrictions based on proactive dam management and outlet limitations.	Will allow assessment of how hard the reservoirs are functioning and how rapidly storage fluctuates. To assist interpretation the full records will be shown along with a number of selected individual years or year sequences.
Irrigated area	Twelve irrigation areas representing each of the main sub-catchment or irrigation scheme areas, refer Figure 1.	Water demand, supply and supply reliability percentage by volume (i.e. volume supplied/volume demanded)	Will allow spatial and temporal variations in supply reliability to be assessed. To assist interpretation the median year, a 1 in 5 year drought, a one in 10 year drought, the worst year and the worst three year period will be produced.
River flow node	Four main stem nodes • Falls Dam inflow • Below Falls Dam, • Ophir • Campground. Where possible downstream (above Manuherekia confluence) nodes for the seven tributaries: • Dunstan Creek • Lauder Creek • Thompsons Creek • Chatto Creek • Ida Burn • Pool Burn • Manor Burn	Average daily flow.	Will allow spatial and temporal variations in flow to be assessed. To assist interpretation the following standard hydrological statistics and plots will be produced for each site: • Minimum flow • 7 Day MALF • Annual days below set minimum flows. • Mean flow. • Medium Flow. • A flow duration curve – with a focus on lower quartile flows. • Hydrographs which focus on below low average flows for the median year, a 1 in 5 year drought, a one in 10 year drought, and the worst (i.e. highest number of days below set minimum) year on record.

6.0 KEY MODEL INPUT DATA SETS – THEIR DEVELOPMENT AND KEY ASSUMPTIONS

The key model inputs data sets are summarised in the table below:

Input data type	Locations	Developed from	Key Assumptions and Comment
Reservoir details including storage size, outlet details, management practices.	Falls Dam, Poolburn Reservoir Manorburn/Greensland Reservoir	Details for Falls Dam are already included in the existing GoldSim model. Some additional information will be required for the Poolburn and Manorburn / Greensland reservoirs which will be sourced form Ida Valley Irrigation Company if required.	The Ida Valley storages are managed on a multi-year basis. To reflect current practice the intent is to impose a seasonal limit on supply which is based on storage at the start of the season. Irrigation is from stored water and the Ida Valley dams are assumed not to contribute to minimum flows. Falls Dam is managed on a seasonal basis with the aim of active storage being depleted at the end of the irrigation season. To reflect current practice proactive dam management (supply restrictions) will be incorporated. Typically Falls Dam will be modelled so that water enters the dam, is allocated based on available storage and then is discharged all within a single time step. A management option that allows allocation to be based on inflows will also be included as well as an option that stored water is not used to support minimum flows. Falls Dam hydro-generation will not be considered. Evaporation from or rainfall on the reservoir surface will not be considered nor will leakage from the dam.
Input flow series above takes and reservoirs	Falls Dam inflow	Raineffects time series from 1972-2012 to be extended using the same method.	As documented in Raineffects report.
	Poolburn Reservoir inflow	Previous inflow series have been developed by both Peter Brown and NIWA (Roddy Henderson).	Peter and Roddy will work together to develop an agreed inflow time series. Note this inflow time series included some water transferred from the Taieri Catchment.
	Manorburn/Greenland Reservoir inflow	Recent work by Raineffects for Galloway Irrigation Scheme (IS). Will require extension of the record if possible.	As documented in Raineffects report. The system is complicated with significant water transfers which will result in considerable uncertainty in the hydrological information. Part of Galloway IS is sourced from the Lower Manor Burn and also includes Crawford Hills/Dip Creek.
	Dunstan Creek Lauder Creek Thompsons Creek	Previous flow series have been developed by both Peter Brown and NIWA (Roddy Henderson via TopNet). The series are based on the Dunstan Gorge , Lauder at Cattle Yards and Thompsons at Weir flow records.	Peter and Roddy to work together to develop an agreed flow series.
	Chatto Creek	There is limited data for this sub-catchment. NIWA (Roddy Henderson) developed a flow series using TopNet.	
	Ida Burn catchments Pool Burn other catchments	Limited work has been undertaken on the Ida Burn and Pool Burn catchment and there are limited flow records.	Peter, Roddy and Dave to work together to develop and agreed flow series.

Input data type	Locations	Developed from	Key Assumptions and Comment
	Mt Ida Race	Flow records are available from the Johnstone weir but will need to be extended. Peter Brown, Dave Stewart and David Hamilton have all previously assessed the Mt Ida Race Flows. Additional information is available for the Hawkdun Idaburn Irrigation Company raceman Keith Campbell.	
Irrigation areas	Area irrigated per irrigation type (spray and flood) and supply source	Various irrigation maps are already available, although there is need for some collation and verification. Peter Ravencroft of ORC has agreed to lead this task.	Input from the water users (namely the irrigation schemes and the consent applicants) will be required to confirm irrigated areas and irrigation types. Irrigation areas will be lumped within each sub-catchment and will be assumed to have a common intake site.
	Irrigation demand	Peter Brown undertook soil moisture modelling to assess irrigation demand and return water for MCWSG. There is need to update and extend the available records.	Two types of irrigation (spray and flood) and three irrigation zones (Above Ophir, Below Ophir and Ida Valley) will be considered. Historic climate 1973-2019 will be used with no consideration of climate change. Climate change impacts on water demand and water supply will be assessed separately as a subsequent stage of the project if required.
	Primary Secondary takes	The current GoldSim model for the Manuherekia catchment considered primary (current) and secondary (new future) takes. The new GoldSim model will focus on current takes only all of which will be assumed as primary. The ability to include secondary takes will be included in the initial model build.	There is potential within the GoldSim model to prioritise the takes. Initially all current takes will be considered to have equal priority.
Minimum flow details	3 main stem locations • Below Falls Dam • Ophir • Campground Tributaries to have various minimum flow sites, refer to Table 1.	Minimum flow levels will be determined as part of scenario settings.	
Allocation priority	Minimum flow top priority then irrigation from upstream to downstream . Take demand initially met from run of river and then from storage where available.	The current GoldSim model for the Manuherekia catchment includes an allocation priority as outlined. The new GoldSim model will have a similar allocation priority.	

IAN LLOYD
Senior Water Engineer
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