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David Mares

NorthConnex

WINNER: OVERALL

Name:	David Mares (on behalf of LLBJV Survey Team)
Position:	Survey Manager
Company:	Lend Lease Bouygues Joint Venture
Name Project:	NorthConnex
Client:	Transurban

Category:

- ☐ Design & Visualisation
- ☐ Survey & Construction
- ☐ Drainage, Sewer, Utilities & Rivers
- ☒ Customisation
- ☐ 12d Synergy

lendlease

BOUYGUES CONSTRUCTION AUSTRALIA

NorthConnex

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Description of Project:

The NorthConnex project is a joint venture between Bouygues Construction Australia and Lend Lease to construct a nine-kilometre tunnelled motorway. When complete, the motorway will link Sydney's north to the orbital network and form part of the National Highway route.

The link between the M1 and M2 is recognized as a high-priority project by Infrastructure Australia and in the NSW Government's *State Infrastructure Strategy* and *Long Term Transport Master Plan* as important for freight traffic, for the wider connectivity within NSW, to reduce congestion, and improve traffic flow along Pennant Hills Road.

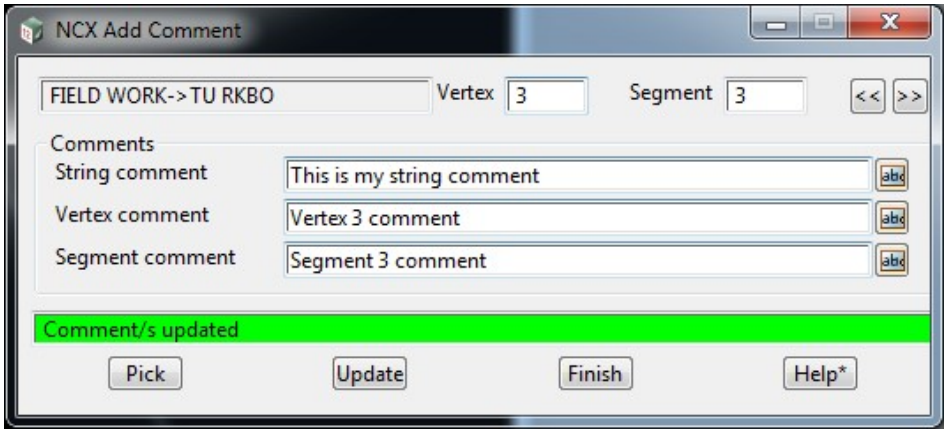
The A$3 billion project, consisting of a construction budget of A$2.65 billion, will be funded through toll charges, with a contribution from the NSW and Federal Governments of up to $405 million each.

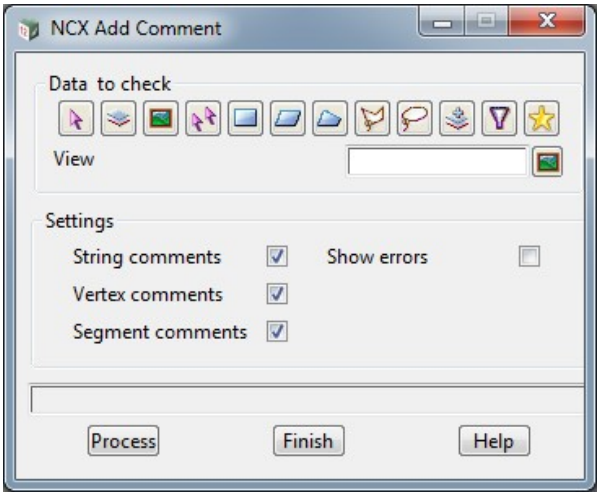
Scheduled for completion in late 2019, the project is the largest road tunnel project ever undertaken in Australia, presenting unique challenges in the design, survey and construction and opportunities for innovative solutions to deliver a successful, cost-effective, and high-quality project within tight timeframes.

Description of problem faced / task undertaken:

Volume of Work

The tunnelling portion of this project involves, at its peak, the use of 19 road headers for tunnel excavation (a record in Australia). For a great deal of the construction period, all these machines will be in use simultaneously and operating on a 24/7 schedule, requiring a correspondingly high amount of construction survey for setout, as-





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built, conformance and much more. In addition to the tunnelling, other construction activity includes the northern and southern interchanges- some 3km of road- and bridge-widening. As such, the project will require the creation, capture and verification of an extraordinary amount of design, survey and construction work, under constant time, cost and quality pressures.

Survey Specifications and Quality Assurance

Adherence to survey specifications (e.g. G71 Construction Surveys) and best-practice procedures by large-scale civil contractors has traditionally been quite low. NSW *Roads and Maritime Services* (RMS), the State Road Authority, has recently indicated it is taking a hard-line approach to the way surveying is managed on projects and committed itself to conducting more extensive and frequent audits. NorthConnex, as a large, high-profile project, will be held to a high standard of quality assurance and adherence to the specifications, requiring innovative solutions in survey procedures. Traditional surveying practices and workflows will not meet those needs.

Field Procedures and Survey Deliverables

Due to the size and scope of the project, many surveyors will be required over the duration of the project. These surveyors will come from a wide range of backgrounds with high variation in:

- Survey coding standards (if present at all);
- File and model naming conventions;
- Data management procedures (formal or otherwise);
- Production of plots, reports and other outputs;
- Skill level and experience; and
- Minimum levels of acceptable quality.

The project, if it is to be not only successful, but innovative, must adopt new and novel ways of managing a diverse survey workforce to ensure a consistently high-quality and time-efficient output.

How the problem was solved:

12d Model was extensively customised with the primary aim of tackling the problems listed above. Customisation covered the entire extent possible, including:

- User interface – toolbars, views, user menus, workspaces, environment configurations and files
- Naming and style conventions – names, colours, mapping files, line styles, symbols, text styles
- Plotting, reporting and outputs – plotters, custom report templates (XSLTs), custom reports
- Processes – custom macros and chains
- Integration – integration with, export to and import from other software, including 12d Synergy, Geodata (machine control and guidance), Kronos (convergence and monitoring), WINTP (drilling & bolting)

Several descriptions of these macros refer to the overall survey process and particular aspects of it. For further details, refer to the attachments included with this submission. Of particular note are the Location and State. Location indicates where the survey was done in relation to one of seven predefined areas. State indicates the type of survey done- e.g. As Built, Pickup, Conformance- based on one of nine predefined values.

The following is a list of some of the 12d Model macros created specifically for the NorthConnex to streamline workflows and deliver an innovative, high-quality infrastructure project.

1. **NCX_add_comment_panel.4do** – Allows field surveyors to attach comments to strings, vertices and segments of their field data, as a replacement for field notes. The data is stored as attributes and flows through the entire project lifecycle from initial field survey, through reviews and import into the Central Data Model (CDM) to the eventual consumption of the data again by surveyors or other groups.
2. **NCX_add_process_attributes.4do** – A utility macro, primarily used in chains, that adds attributes to data to record and track its progress at each stage of the workflow. Currently, data is tagged with

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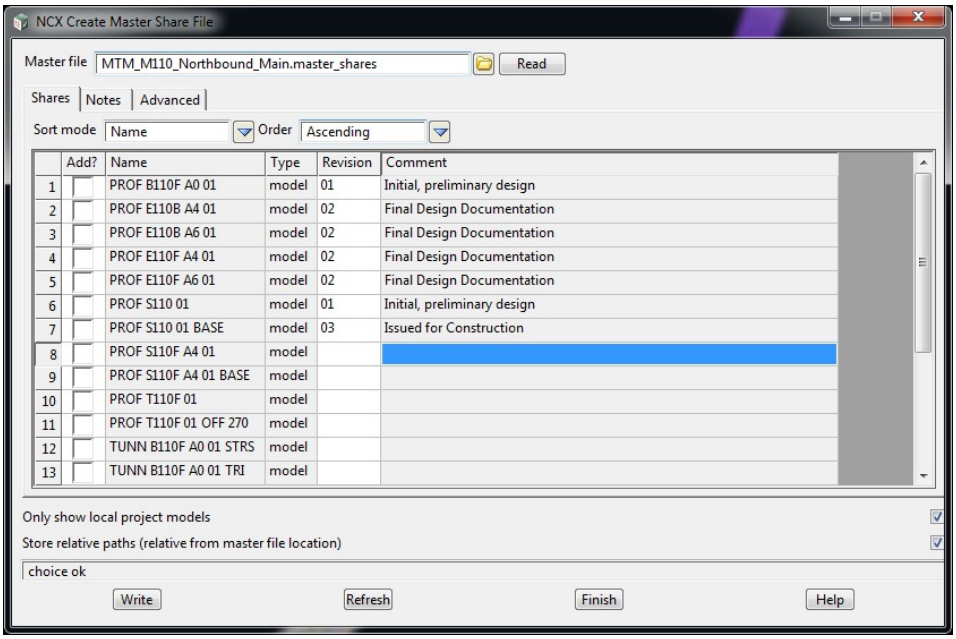

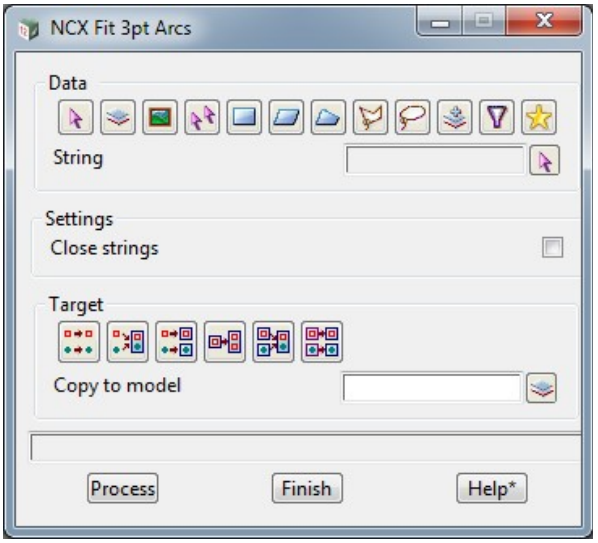

information when it is captured in the field, submitted as raw fieldwork, processed for edits, submitted as post-processed fieldwork, reviewed, approved or rejected, and imported into the CDM. Thus, an audit trail is created for each survey on the project that lives with the data and can be called upon at any time.

3. **NCX_add_username_project_attribute.4do** – Run at project start-up to automatically assign the currently logged-in username to a project attribute. This is then further used to populate 12dField attributes, title blocks and plots, standardise export filenames, and to log usage and errors.
4. **NCX_approve_data_panel.4do** – Used by survey managers to approve or reject submitted fieldwork after review. The manager selects a set of data to approve- having already been reviewed and prepared for CDM import. On selecting a data source, the data is checked for consistency of Location and State and to ensure it came from the same file. This last point is critical to ensure a piece of data in the CDM can be tracked back through the entire survey process to its original fieldwork file. The manager can then Approve or Reject the data, providing a reason for doing so. Once the file is processed, attributes with the approval/rejection details are added to the data and appended to the text file, before a 12daz is created in the corresponding CDM Survey project. This macro is also integrated with 12d Synergy, updating the review status of the files in 12d Synergy and adding the updated data.
5. **NCX_check_comments_panel.4do** – Checks a given set of data for the presence of comments created via the NCX_add_comment_panel.4do macro. This allows others- managers, reviewers, other surveyors- to quickly and easily inspect data for any additional comments that might be of use.
6. **NCX_create_master_share_file_panel.4do** – Creates a master share file (MSF). Although 12d Model already contains the ability to create master share files, this macro adds several enhancements. 12d Model projects opened from 12d Synergy can only create Master Share Files using Synergy paths (Synergy12d://). This macro allows such projects to create MSFs using traditional Windows filesystem paths (e.g. C:\ ), thereby allowing users to continue using and subscribing to the Central Data Model without installing 12d Synergy. The macro also allows for additional information- Revision and Comments- to be stored with the Master Share File providing end-users with the information needed to determine the suitability and currency of the data being built. The list of shared data can be sorted by various means- alphabetical, type, last created data, last modified date, etc- making the management of large model lists much easier. Finally, the panel is able to create Master Share Files without all additional features to maintain backwards compatibility with other 12d Model users and versions.

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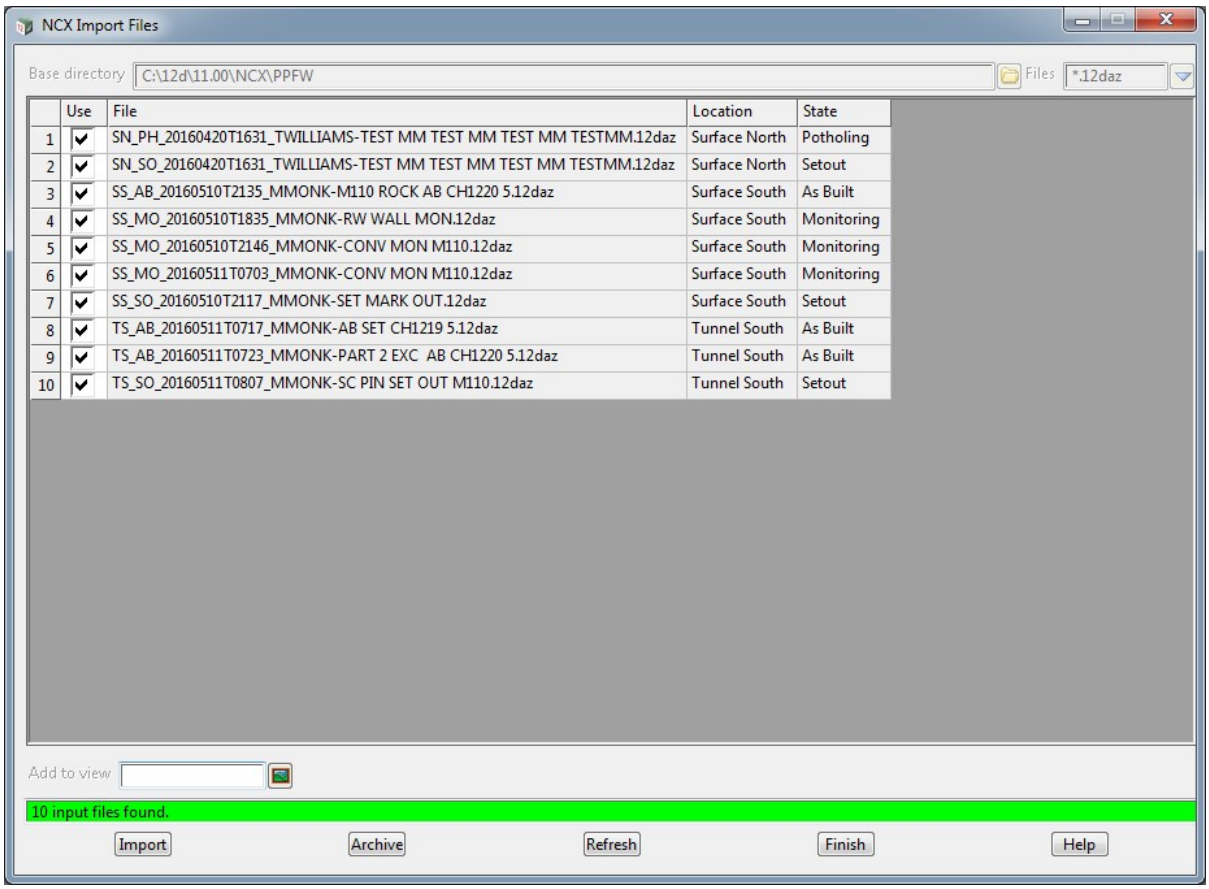
7. **NCX_export_survey_fieldwork_panel.4do** – One of the most important and most used macros for surveyors on this project. This macro is run by the field surveyor once a survey task is complete.
   i. Source model is populated with the default ("FIELD WORK"), but can be changed;
   ii. Source data is read for 12dField attributes, to determine and verify the corresponding FLD file;
   iii. QA checks are run on the source data and corresponding FLD file:
      - Location is the same for all data (12dField attribute Lot Number);
      - State is the same for all data (12dField attribute Category);
      - Surveyor name is the same for all data (12dField attribute Surveyor);
      - All instrument serial numbers are the same and the instrument's calibration and collimation is up-to-date (checked against a master list of calibration data);
      - Setup residuals – Helmert or Backsight – horizontal and vertical;
      - Number of faces used for setup (i.e. ensure multi-face) (in V12 only);
      - Number of points used for Helmert setups;
      - Target heights used for setup;
      - Check shots at the start, end and every 1 hr; and
      - Maximum distance of check shots.
   iv. A QA Class (letter A to G) is assigned based on Location (Surface vs Tunnel), Instrument Type (TPS vs GPS) and project minimum;
   v. Summary of QA check results are shown in a simple interface- green = OK, red = BAD, yellow = problems- allowing the user to quickly and easily see problems with their survey;
   vi. Detailed QA check results and error messages on the Messages tab;
   vii. User can provide an additional comment (max. 30 chars) to describe the fieldwork done;
   viii. Surveyor can choose to move the submitted fieldwork to a new model or export to a 12da, so they have a local copy of their survey;
   ix. Filename for export is standardised across the entire project and includes:



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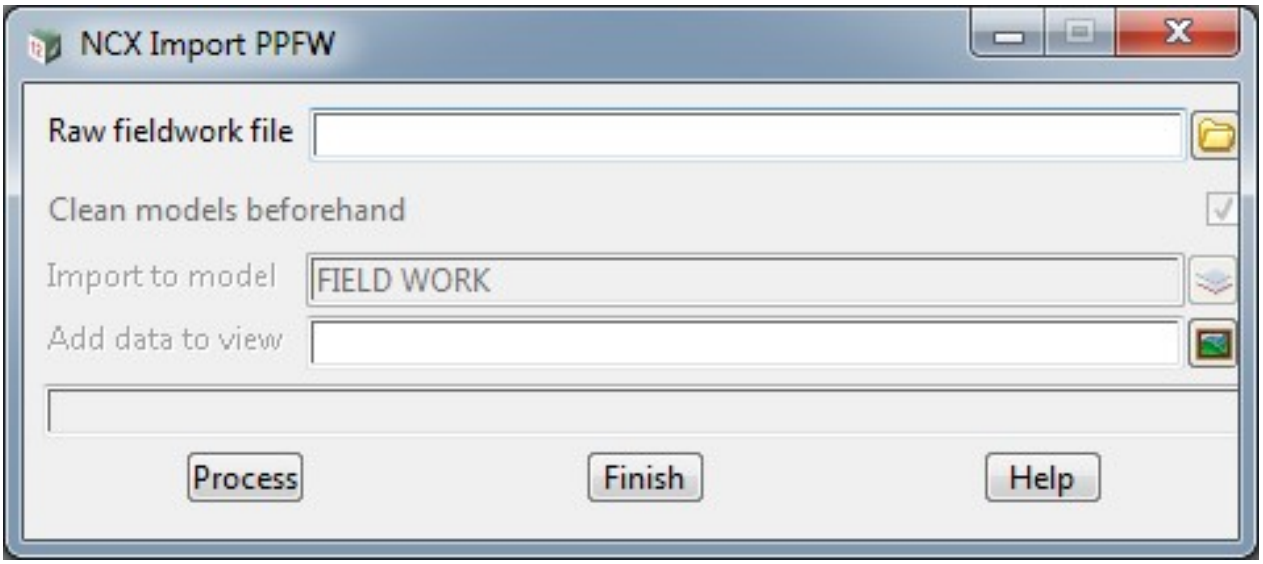

- Location, State, Timestamp, Surveyor, Quality Checks and Comments
  e.g. TN_AB_20160510T1214_CHOGAN-SHAFT EXCAVATION

x. Files exported to CDM location for upload to Synergy (FLD, txt and 12daz); and
xi. Existing FLD file and source model are cleaned, ready for the next survey task.

8. **NCX_file_prompt_panel.4do** – Creates a user-customisable panel at run-time for selection of a file. Intended for use in chains, this macro allows the chain author to create custom panels for selecting files by passing various settings as command-line arguments to the macro. The macro reads this information and dynamically creates the panel to reflect this information. The user can specify the panel title, file box label, file box mode (e.g. File Must Exist, File Create, etc.), wildcard (e.g. *.12daz) and whether the field is optional. This macro provides much more flexibility than available from the native chain prompt command without creating custom macros for each specific use or a generic macro that is vague or confusing to the end-user.
9. **NCX_Fit_3pt_arc_panel.4do** – Fits arcs through 3 points surveyed as straight lines. All tunnel shafts on this project have curved shotcrete walls between piles. These need to be surveyed at every metre vertically. This macro allows the surveyor to pick-up the curved walls with 3 points- e.g. start, middle and end- and straight lines as quickly as possible and later fit arcs to these strings to better represent the actual conditions and allow for accurate conformance checks and as-built plots. The arcs can also be closed to allow for survey of piles by 3 pts or other circular objects (e.g. trees, water tanks). All edits are done non-destructively so that all the rich attribute information collected in the field and throughout the data's life is retained.
10. **NCX_import_files_panel.4do** – Allows for the batch import of numerous files at once. Intended primarily for the import of the hundreds of fieldwork files generated by the survey process into the Central Data Model projects. A custom grid lists all files in a given CDM project- files created from the review and approval process- as well as the project Location and survey State for each file. The user can tick all files at once or individually and import the selected files. Files are imported one-by-one and then automatically moved to sub-folders (with date/time) to prevent duplicates and track progress in 12d Synergy.

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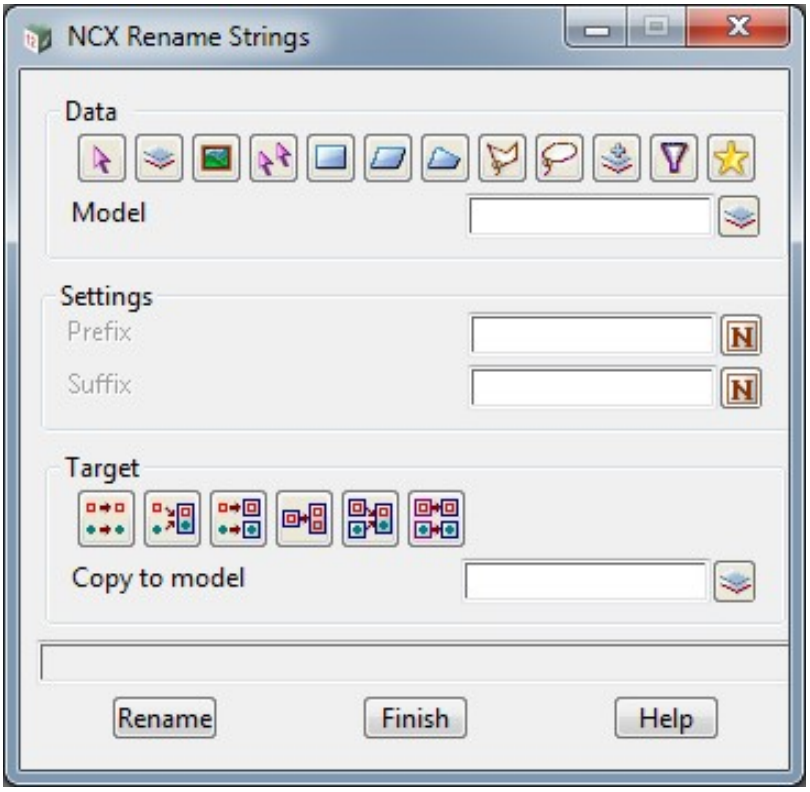
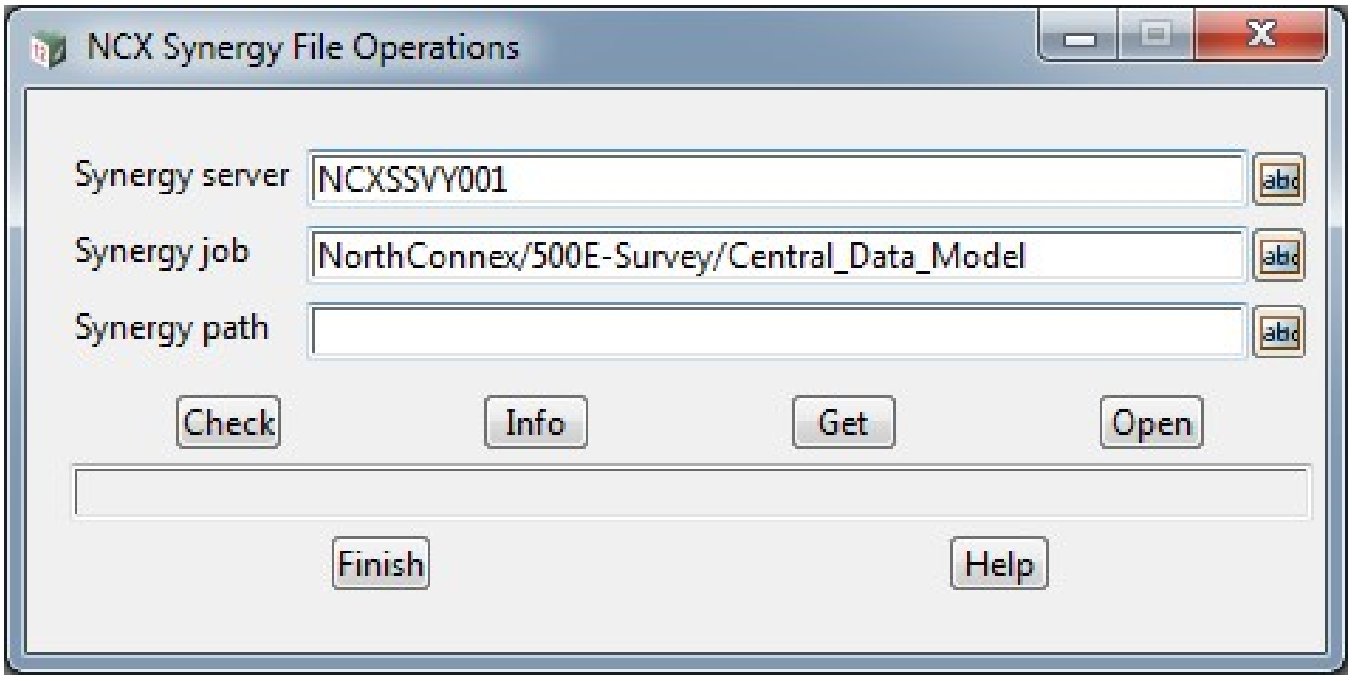
11. **NCX_import_ppfw_panel.4do** – Import raw fieldwork for post-processing by the surveyor. The macro prompts the user to select a file to import- that file having already been created in the current project via the NCX_export_survey_fieldwork_panel.4do process. The macro then cleans out any existing data in the target model (FIELD WORK), reads the 12daz data, moving the data to the target model (FIELD WORK) and adding attributes to the imported data of the process workflow (time, date, computer, user, filename, etc.).
12. **NCX_open_file.4do** – A utility macro to open a file in a specified program or with its associated program. This macro is run without user interaction- command-line arguments passed to the macro make this macro ideal for opening files from chains. For example, opening plots, outputs, reports, intermediate results and check files.
13. **NCX_open_synergy_file_panel.4do** – Much like NCX_open_file.4do, this is a utility macro intended to allow for opening a file stored in 12d Synergy with a user-specified program or the files associated program. This is effectively a "wrapper" around the 12dSynergyCmdLine.exe command line client for 12d Synergy, allowing a 12d Model user to interact with 12d Synergy in a basic manner without opening the 12d Synergy client. This macro allows the user to check (if file exists), open, get (download) and view information (info) files in 12d Synergy. This macro can also be run from a chain to automate such 12d Synergy operations.
14. **NCX_rename_strings_panel.4do** – A utility macro that is used to rename strings by providing a prefix and/or suffix. The macro can either be run with a full graphical interface or non-interactively via command-line arguments providing the flexibility to use it in a wide range of situations and for various automation purposes.
15. **NCX_report_removed_mark_panel.4do** – Provides field surveyors with an easy and convenient way of reporting any survey control marks that are missing on-site. Survey controls are regularly knocked, removed, destroyed and replaced both on the surface and in the tunnels. The surveyor can simply select a control point to report as removed or missing from their tablet. The reported mark is highlighted as removed and the details logged to a file on the tablet (allowing for reporting without a network connection). The report file is then uploaded to the Central Data Model as part of the overall process,



compiled with other reports and used to update the Master Survey Controls project used by all surveyors on the project.

16. **NCX_set_location_state_panel.4do** – This is used by surveyors and managers alike, displaying the current values for Location, State and Surveyor (read from attributes). Each of the values can also be changed for all data- for example, when a survey selects the incorrect Location- to ensure accurate and correct data before importing into the CDM. This panel also serves a second purpose by determining the model prefix to be used when mapping data for inclusion in the CDM. The prefix is determined from abbreviated values of the Location and State.
17. **NCX_strip_extension_panel.4do** – A utility macro, this macro takes as an input a file path and populates various other fields with variations on that field, such as file extension, file name without extension, parent directory name, file with no path and path only. This macro is used in chains to perform various file path manipulation operations to access other files or rename/move/copy files.
18. **NCX_submit_data_panel.4do** – A general, all-purpose macro similar to NCX_export_survey_fieldwork_panel.4do, but for standardised submission of non-fieldwork data. The user is able to choose from a wide range of data to submit- 12d Model data, Plots, Files and Notes- with various sub-types (e.g. Photos, videos, audio, calculations, reports, etc.). Depending on the type of data being submitted, the panel will require various different fields to be filled-out before submitting the data. Every submission requires the user to select the Location, State and Reason for Submission. The user can also optionally assign the submission to any given string in the CDM (e.g. road control lines, project or site boundaries, structures, survey control marks). All this information is used to create and submit the data with a standard filename to the CDM uploads location. As with the NCX_export_survey_fieldwork_panel.4do, this panel is designed to submit data for inclusion in the CDM without needing a network connection. The files are exported and queued up, ready to upload whenever a network connection is next available. One final innovation for this macro is the ability to save a history of field values. For example, if a user types text in a field for one submission, this will be saved in the current project and made available for any submission in the future, pre-populating fields and saving the user from having to repeat typing or data entry.



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19. **NCX_subscribe_master_share_file_panel.4do** – Although 12d Model includes a native panel for subscribing to master share files, its usability on touch-enabled tablets is far from ideal. The current panel requires right-clicks (difficult on tablets with Windows), browsing through file structures, and repetition. This new panel was designed to provide a much easier and quicker way for surveyors to subscribe to master share files from a tablet. The macro searches the local CDM directory for all master share files (.master_share), populating a grid list of all files that can be individually selected and subscribed to by simply ticking the box and clicking process. Already a substantial usability improvement of the default 12d Model panel, the macro makes subscribing to standard datasets even easier. A configuration file (XML-based, included with the macro) defines subscription presets. Each subscription preset can reference multiple master share files. For example, a Design North preset could include the northern design, cadastral, imagery, survey controls, control lines and northern tunnel master share files. Thus, rather than need to tick multiple master share files to subscribe to, the user can simply select a preset and subscribe to all relevant master share files automatically. Finally, the graphical interface of presets- tick boxes in groups- is built dynamically every time the macro is run based on the contents of the configuration file. This allows for maximum flexibility- each new or changed subscription preset does not require a rewrite of the macro. Instead, just the configuration file needs to be changed and the macro interface will be updated when next run to reflect the changes. The macro also intelligently spaces and sizes the panel to ensure it fits on the smaller screens of field tablets.
20. **NCX_tunnel_measure_panel.4do** – Although 12d Model contains a wide range of measure commands, tunnel projects have a unique set of requirements for measurements. Much of the measurements are for true 3d- 3d chainage, 3d dropped distances, offsets, heights and so on. Therefore, a new macro was written to provide these commonly-accessed measurements from a single panel for tunnel surveyors.
21. **NCX_update_12dfield_settings.4do** – This macro is run when a project starts and is used to update various settings for 12dField. Although the 12dField configuration files are standardised and pushed out to all surveyors as part of the CDM customisation, running 12dField can modify these files (since they are local). Surveyors also want to keep some of their modifications, since they can have preferences for a particular setup or behaviour of 12dField. Such modifications are allowed so long as they do not contradict any project requirements. Thus, this macro allows for a combination of user customisations, but also enforcement of project-wide standards. This macro also allows for setting values based on the current user, rather than one setting for everyone. For example, when the project is started, the 12dField setting for surveyor (in 12dF_GLOBAL_CONFIG.4D) is populated with the current user's name (see also **NCX_add_username_project_attribute.4do**). Therefore, when the user starts 12dField, they do not have to change or modify the Surveyor entry- it is already populated with their name and saves them time on a process that is repeated many times per day. Values can be populated from a master file of values, from command-line arguments, from 12d Model variables or from 12d Model project attributes. This macro allows for maximum flexibility of 12dField with a combination of user-specific customisations and project-enforced settings not currently possible in standard, out-of-the-box 12d Model.
22. **NCX_upgrade_reminder_panel.4do** – Run when a project starts, this macro simply checks the current version of 12d Model against a specified minimum version. If the current 12d Model version is older than required, a message will be displayed, asking the user to upgrade. If the 12d Model version is OK, the macro is silent and displays no message. This allows the project to ensure all users are running the same version of the software, minimising support hassles, ensuring consistent outputs and reliable behaviour of 12d Model software.

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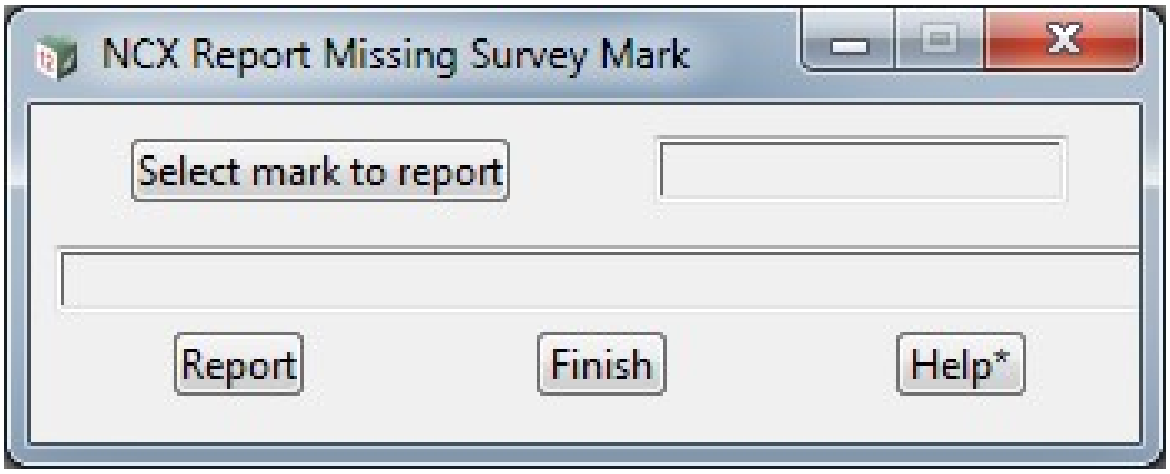

Chains:
Chains in 12d Model allow for the automation and streamlining of simple or complex processes without the need to create dedicated macros and using much of the existing functionality inside 12d Model. Several chains have been written for this project, utilising chain parameter files (PVF), macros, conditional logic and in-built panels.

- Import survey control marks from CSV:
  - Gets current timestamp (for model prefix) (timestamp_panel.4do);
  - Imports CSV file;
  - Maps imported data;
  - Checks for existing models;
  - Creates and populates view; and
  - Automatically prompts to update sharing and master share file.
- Import Fieldwork Data:
  - Checks if the "FIELD WORK" model exists and is empty, prompting the user for action;
  - Prompts the user to select a file to import (NCX_file_prompt_panel.4do);
  - Passes the selected file path and gets the stripped file path (no extension) (NCX_strip_extension_panel.4do);
  - Prompts the user if they would like to view the corresponding info report file;
  - Downloads and opens the info report file directly from 12d Synergy;
  - Creates and prepares the plan view for import;
  - Imports the selected 12daz file;
  - Checks the "FIELD WORK" model for imported data;
  - If empty, prompts the user to move data to the "FIELD WORK" model;
  - Adds process attributes to the imported data (NCX_add_process_attributes.4do); and
  - Add fieldwork model to view, fit and redraw.
- Map Fieldwork Data for CDM import:
  - Prompts the user for a given dataset;
  - Gets the correct prefix for mapping based on the source data location and state (NCX_set_location_state_panel.4do); and
  - Maps the data to models for eventual import into the CDM.
- Export monitoring data to CSV:
  - Exports a given set of surveyed monitoring points to a CSV in a format compatible with the Kronos convergence and monitoring system.
- Create Controls View:

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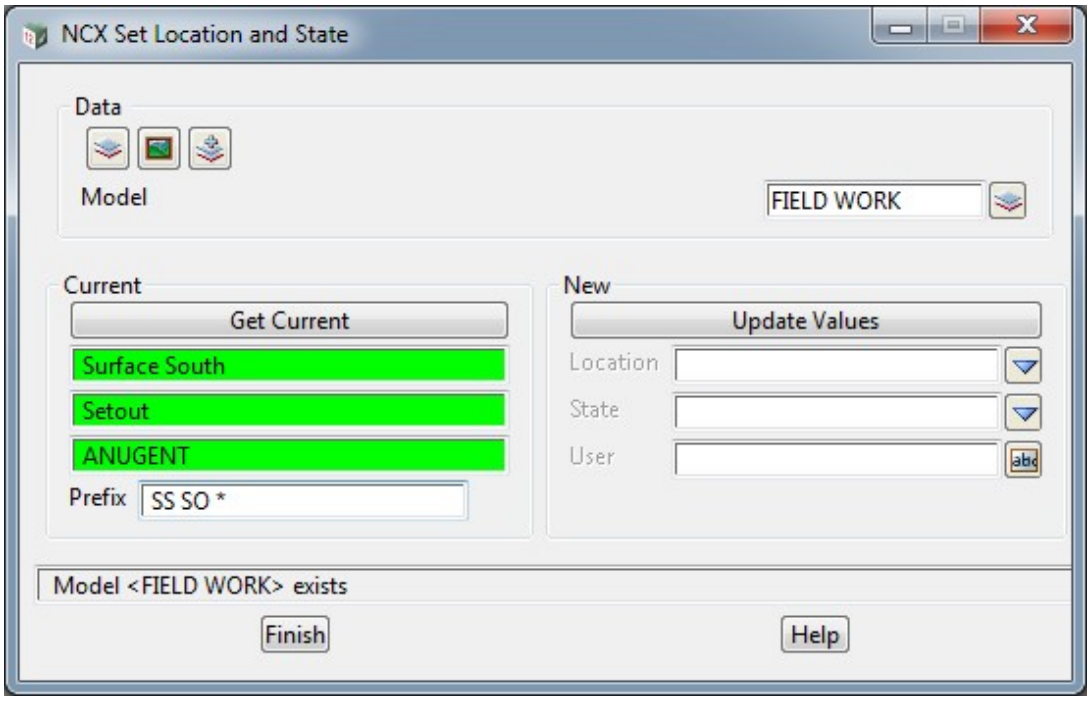
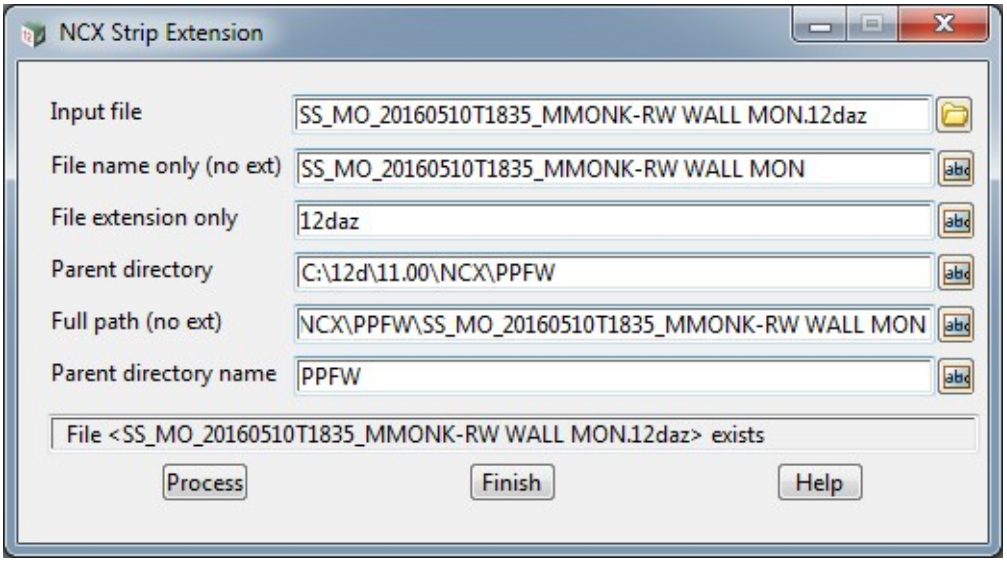
- Checks for the existence of a “Controls” view, creating it if necessary; and
- Adding the latest survey control marks and design control lines models to the view.

Custom reports and plots:

- Tunnel Conformance – the output of the Tunnel Conformance Plot and Report have been heavily customised to adopt project styles (e.g. logos) and present the critical information in a user-friendly way. Refer to the attached sample data for examples.

Taken together, this suite of extensive and innovative customisations of 12d Model solves many of the most common problems encountered by construction surveyors on projects of any size, providing a robust data management process and eliminating manual file handling, haphazard naming conventions and poor-quality surveys.





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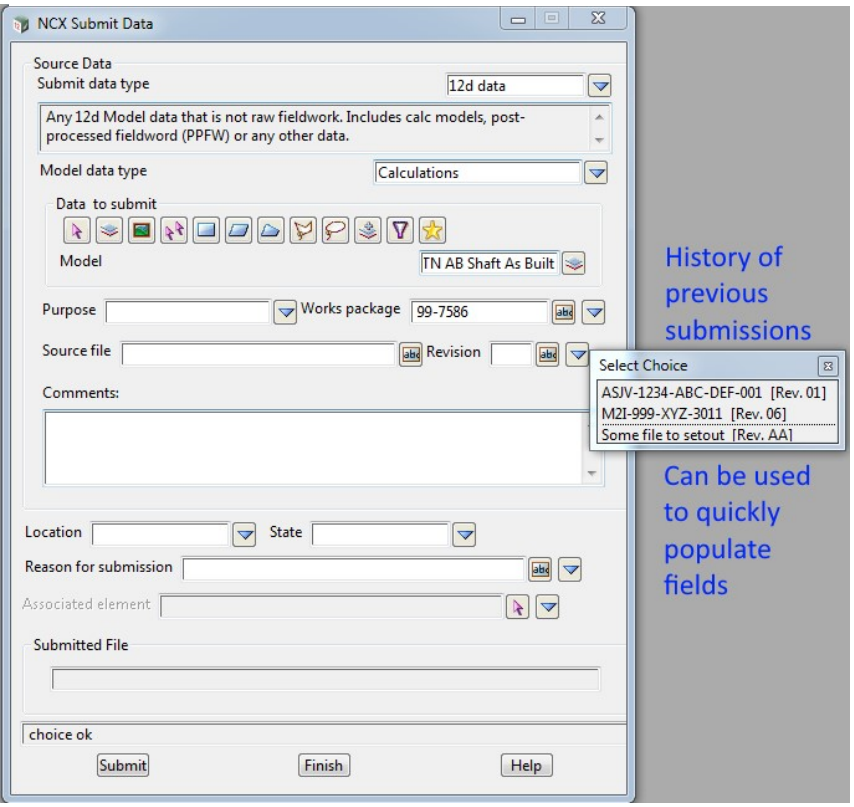

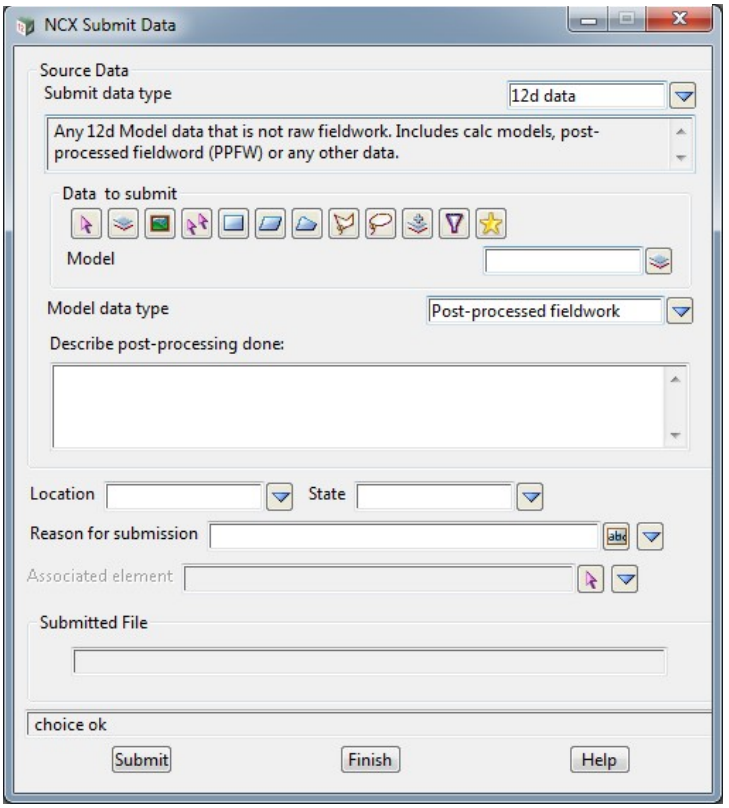

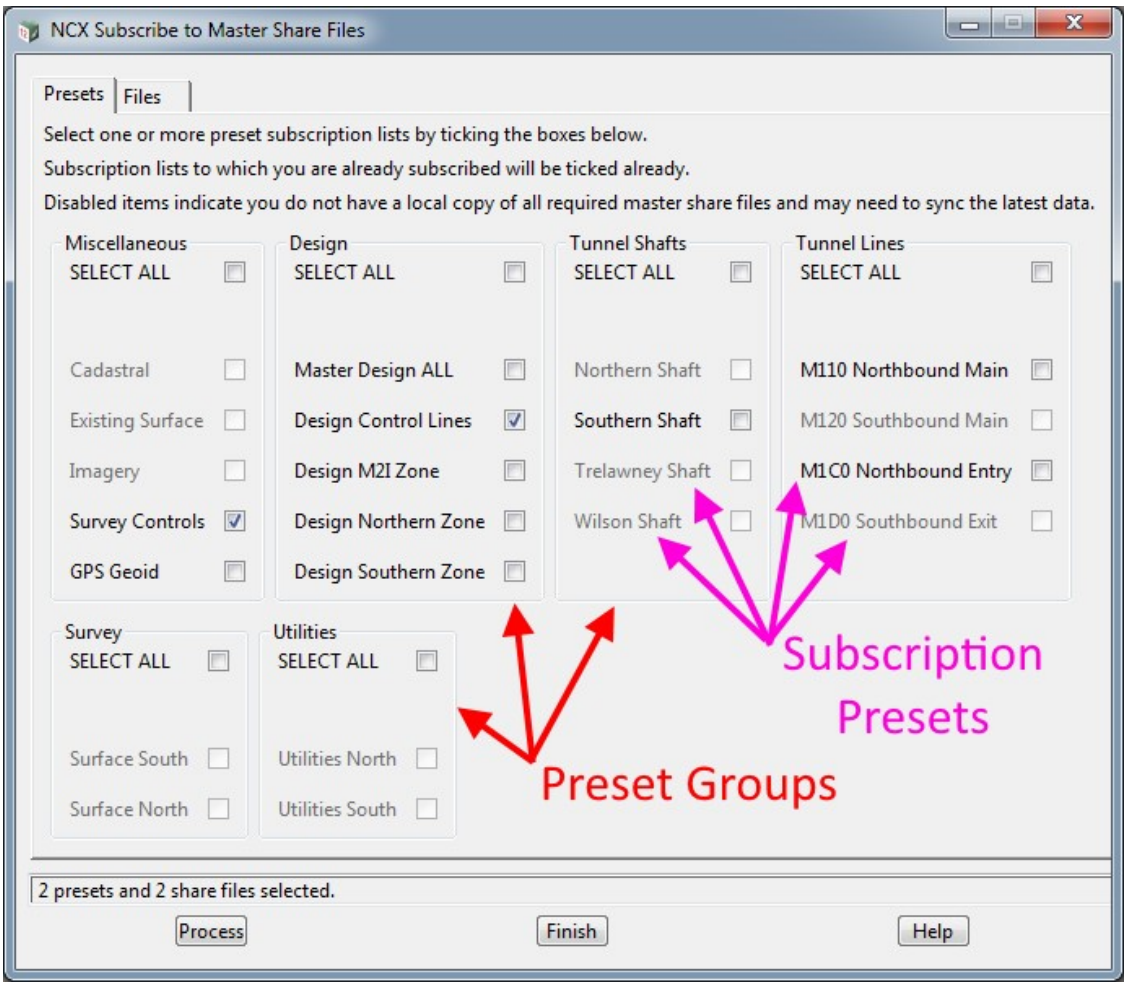

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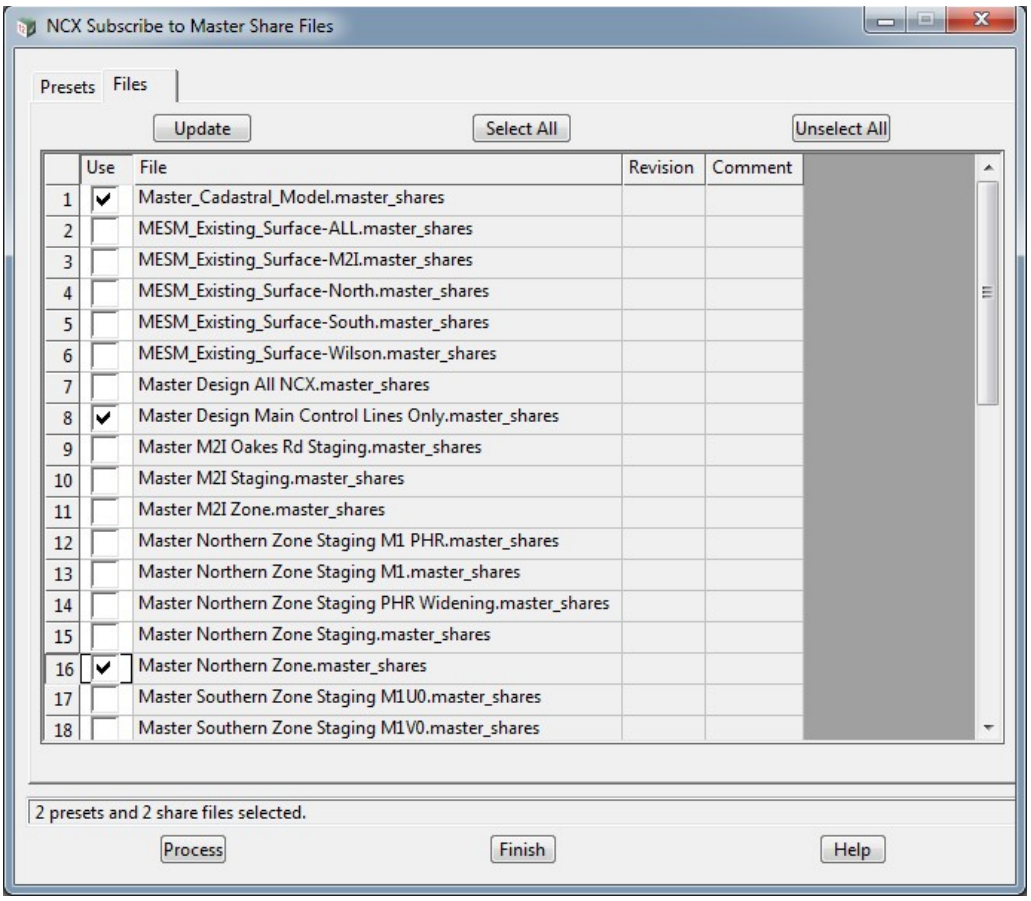

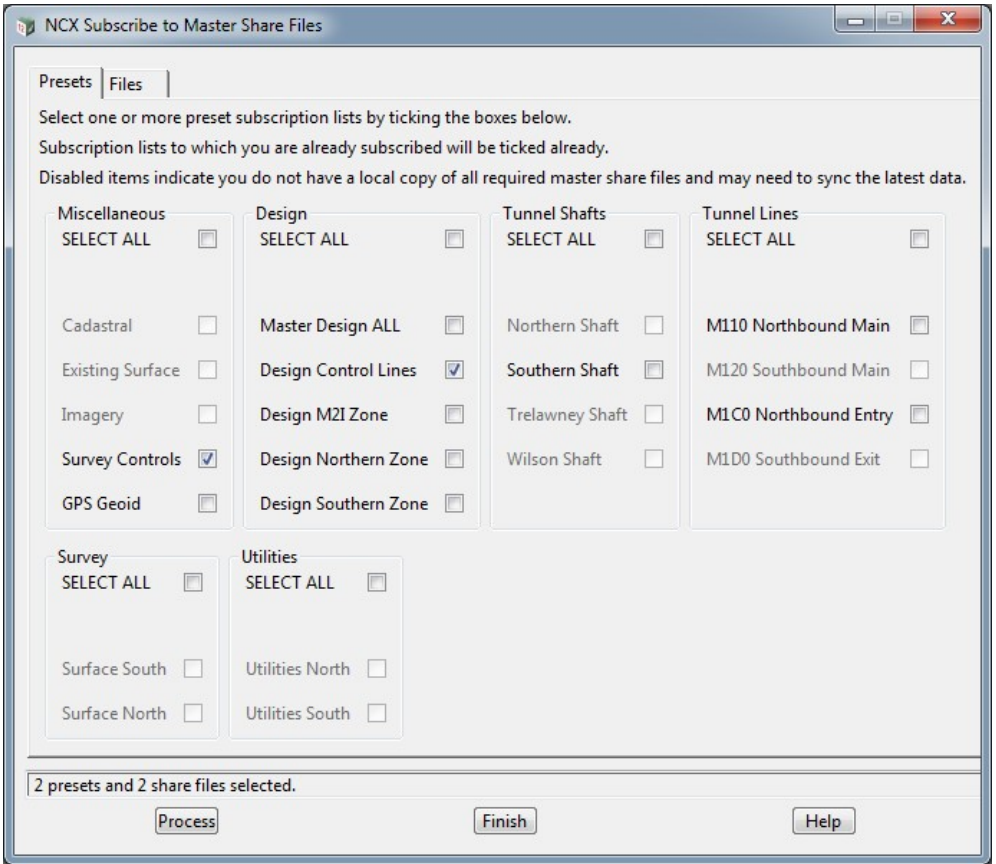

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